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REANALYSIS AND APPLICATION COMPUTER PROGRAMS FOR IMPROVING ARTI--ETC(U)

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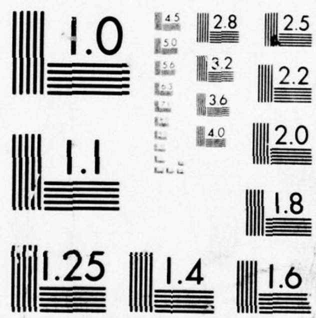
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Final Report

January 1976

REANALYSIS AND APPLICATION COMPUTER PROGRAMS FOR IMPROVING ARTILLERY ACCURACY

by

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and

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Prepared for

ATMOSPHERIC SCIENCES LABORATORY
U.S. ARMY ELECTRONICS COMMAND
WHITE SANDS MISSILE RANGE, NEW MEXICO 88002

Contract DAAB07-74-C-0181

SRI Project 3395

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ABSTRACT

Two programs have been developed for using both Air Force Global Weather Central (GWC) prognostic data and Army rawinsonde data for improving the accuracy of meteorological corrections applied in aiming cannon artillery. The first program, the Prognostic Data Reanalysis Routine (PDRR), updates the GWC prognoses using the available Army rawinsonde observations. The program options include data editing, updating for both current and later times, divergence alteration, and height balancing. The second program, the Artillery Applications Routine (AAR), uses the updated GWC results in addition to the best available sounding, to generate a Computer Meteorological Message for use in computing ballistic corrections for artillery firings. The options that are to be used in either program are determined by control parameter values that are initially read from data cards into the computer. A description of the numerical techniques and the computer program input and output are given in this report, along with a listing of the programs and an example case.

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I INTRODUCTION

Artillery accuracy is significantly dependent on accurate and detailed information regarding weather conditions (Shinn and Maynard, 1974).* In particular, wind, temperature, and density affect the motion of a projectile through the atmosphere. Meteorological corrections are made either manually using a Ballistic Message, or by preparing a Computer Met (meteorological) Message (U.S. Army Manual 6-15, 1970). In the second method, a computer is used to determine the ballistic trajectories and the required meteorological corrections. Meteorological information is normally obtained from one dedicated GMD-1 rawinsonde section that is assigned to a division or corps artillery. Various new methods are currently being considered by the U.S Army for improving the accuracy of meteorological information by basing it on five or more rawinsonde observations (Barnett et al., 1974). These methods include:

- Best available--This method is based on using the observation with the minimum time-distance deterioration factor. The variability over 30 km is approximately equivalent to that for a 1-hour-old message.
- Weighted mean--In this method the weighting is based on the time and distance of observation from the artillery firing. This method even with equal weighting proved superior to the conventional approach in tests based on both sounding and artillery data of the NATO "Summerwind" exercise at Meppen, Germany.
- Extrapolated/Interpolated--This method includes several approaches, among them the use of a third-degree polynomial spline for extrapolation of meteorological conditions forward in time and the use of a smoothed plane for interpolation in area.
- GWC/ARTY forecast--This method uses the USAF Global Weather Central (GWC) numerical prognostic products (U.S. Army Force, 1973), and updates them with local U.S. Army artillery rawinsonde data. It is the method described in this report.

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* References are listed at the end of the report.

The GWC/ARTY forecast method provides a very general and versatile approach, since, by suitable adjustment of parameters, it can give results equivalent to those of the other methods. However, by using the GWC products, more reasonable meteorological information should be obtained for future times and for data-void areas. Accurate or just reasonable information regarding the weather over enemy territory would be critical in actual battle situations. Preliminary testing of this forecast method was carried out, using both rawinsonde observations of the National Severe Storms Laboratory (NSSL)* and of the U.S. Army Artillery Met Comparisons. The Artillery Met Comparisons were made at White Sands Missile Range (WSMR) by the Atmospheric Sciences Laboratory (ASL) of the U.S. Army Electronics Command, during November and December of 1974 (ASL, 1974). This report presents results obtained for one of these days--19 November 1974. Results for the test based on the NSSL data have been given in Quarterly Report 3 (Mancuso, 1975).

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*Special upper-air observations have been carried out by NSSL since 1966. The upper-air mesonetwork for 1966 and 1967 consisted of 11 sites separated by about 50 miles. Soundings were generally made up to 100 mb and at 90-minute intervals during periods of expected severe weather. Data for these years were obtained from NSSL (Barnes et al., 1971).

II PROGNOSTIC DATA REANALYSIS ROUTINE (PDRR)

The PDRR program is for reanalyzing or updating the GWC prognostic data, using the most current Army artillery upper-air observations. The data treated are the zonal and meridional wind components (U and V), virtual temperature (T), and pressure height (H). Figure 1 shows the standard GWC polarstereographic grid for the northern hemisphere. Over North America, Europe, and Asia, mesoscale grids are used with mesh lengths half the standard. The PDRR program uses a 5-by-5 section of either the Standard or mesoscale grid. The GWC grid section over White Sands used in this study is indicated in both Figures 1 and 2. Since this lies within the North American mesoscale grid, it covers only a 2-1/2-by-2-1/2 section of the standard grid, and has grid points about 80 nautical miles apart.

When a set of the GWC prognostic data becomes available, the motions or trends of the weather patterns are determined for different forecast times and for the different GWC prognostic levels (surface, 850, 700, and 500 mb). The tracking technique used to accomplish this was developed by Wolf (Mancuso and Wolf, 1974). This technique consists of selecting a 3-by-3 matrix of data values (template) from the GWC 5-by-5 grid of data for a given time. The template is then placed at some possible location in the data at the next later time, and in this application an rms difference is computed between the template and the corresponding template location for the later time. The search for a minimum rms starts with the template in its initial position, assuming zero motion; an rms difference is computed and used as the local minimum. Then rms values are computed for the template locations to the right, above, below, and the left.

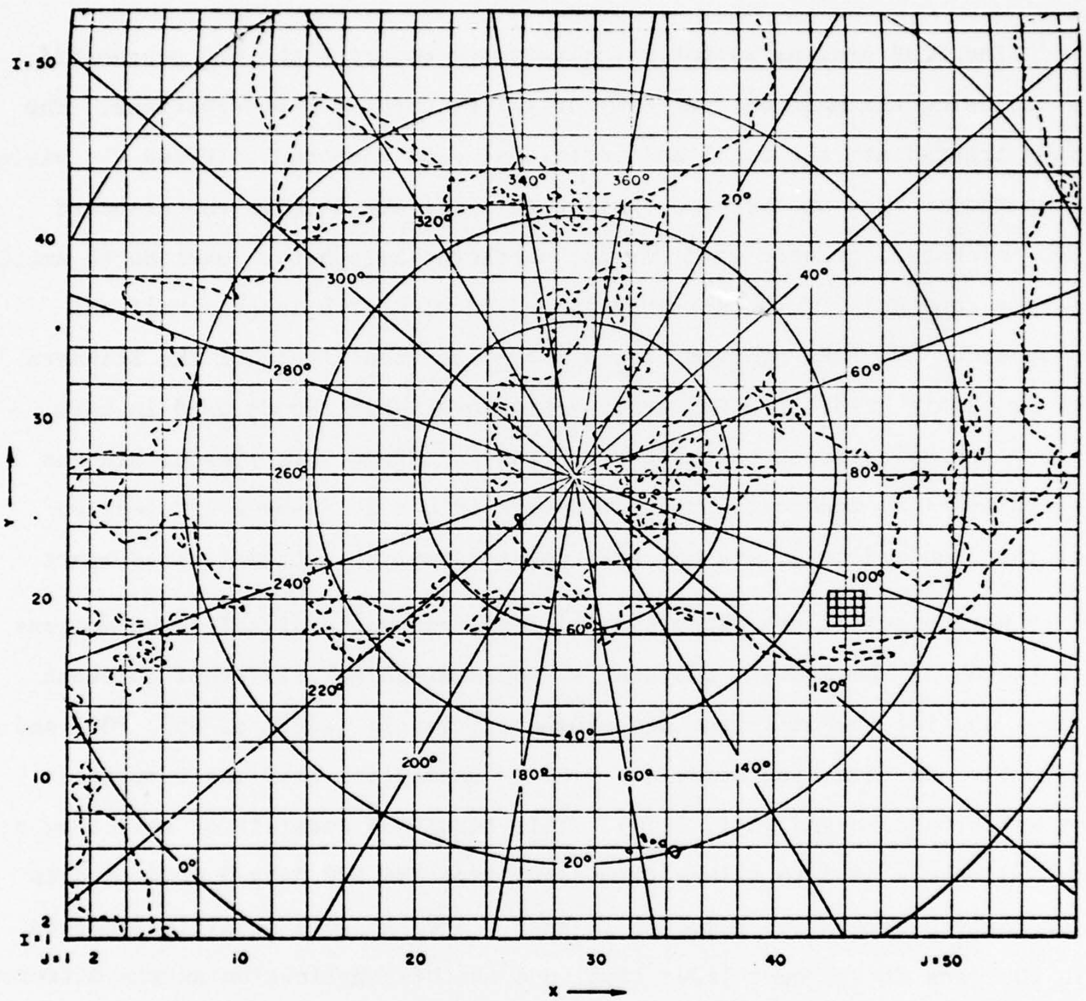

FIGURE 1 GWC POLAR STEREOGRAPHIC GRID (SHOWING THE 5-BY-5 SECTION FROM THE NORTH AMERICAN WINDOW THAT WAS USED IN THE PDRR PROGRAM)

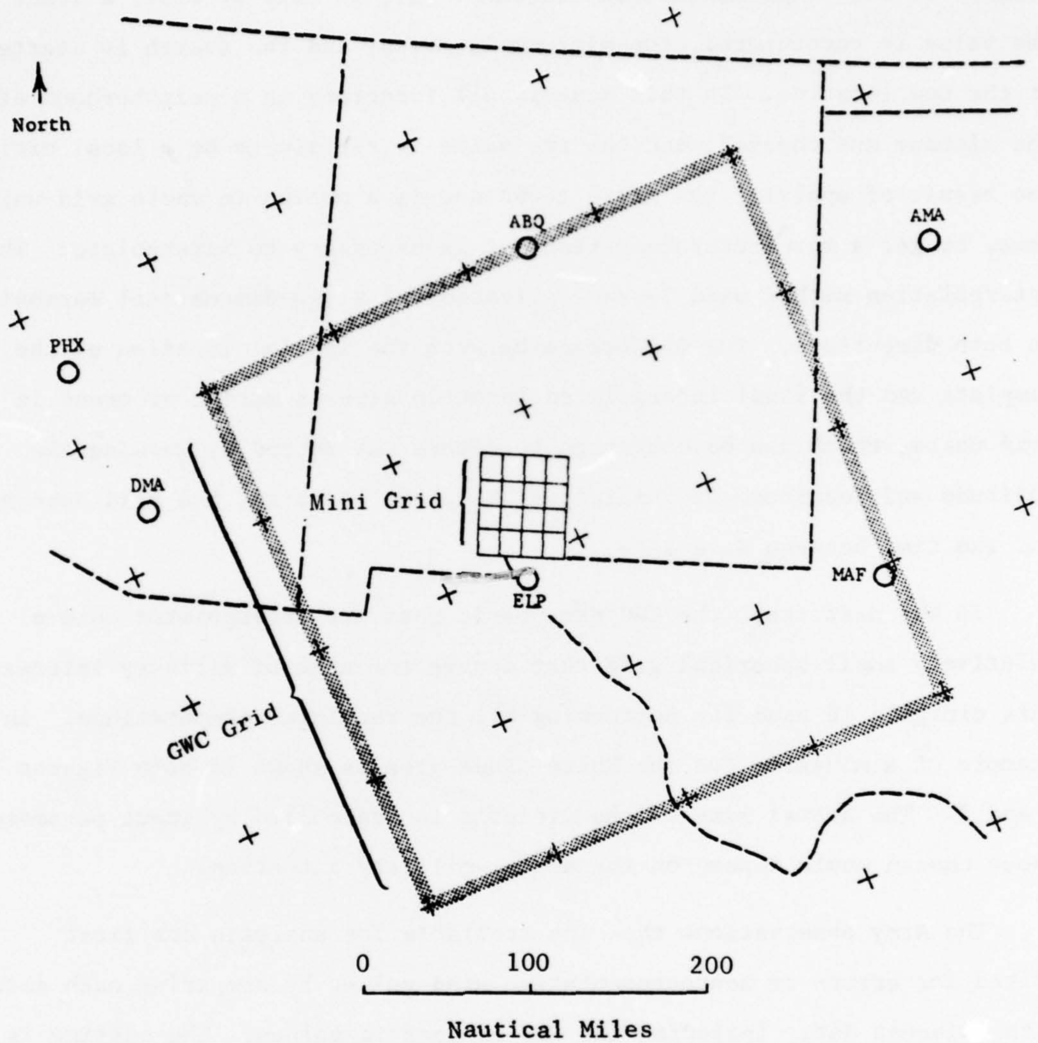

FIGURE 2 ILLUSTRATION SHOWING THE 5-BY-5 SECTION OF THE GWC GRID AND THE MINIGRID

When a lower rms is found, the minimum is moved to the location with the lower rms, and the search begins at the new minimum. When this search ends, with no new minimum having been found, all locations within one element of the final minimum are checked. If, in this process, a lower rms value is encountered, the minimum is moved, and the search is started at the new location. In this manner, all locations in a neighborhood of the minimum are checked, and the rms value is certain to be a local minimum. The result of applying the above technique is a motion in whole grid units. Thus, to get a more accurate motion, it is necessary to interpolate. The interpolation method used is an application of a two-dimensional parabola in both directions. The difference between the initial location of the template and the final interpolated location gives a motion or trend in grid units, which can be converted to meters per second by knowing the latitude and longitude of the initial template location, the grid spacing, and the time between data sets.

In the next step, the GWC prognostic data are interpolated onto a relatively small spherical grid that covers the area of military interest. This minigrid is used for performing all the remaining computations. An example of a minigrid for the White Sands area is shown in both Figures 2 and 3. The actual size of the minigrid is controlled by input parameters; those chosen would depend on the actual military situation.

The Army observations that are available for analysis are first edited for errors or nonrepresentative wind values by comparing each datum with adjacent data, including the GWC prognostic values. The editing is based on a method developed by Endlich et al. (1972). It is accomplished automatically be computing a wind vector at the location of the measurement, using the technique used for computing a grid-point wind (Appendix A).

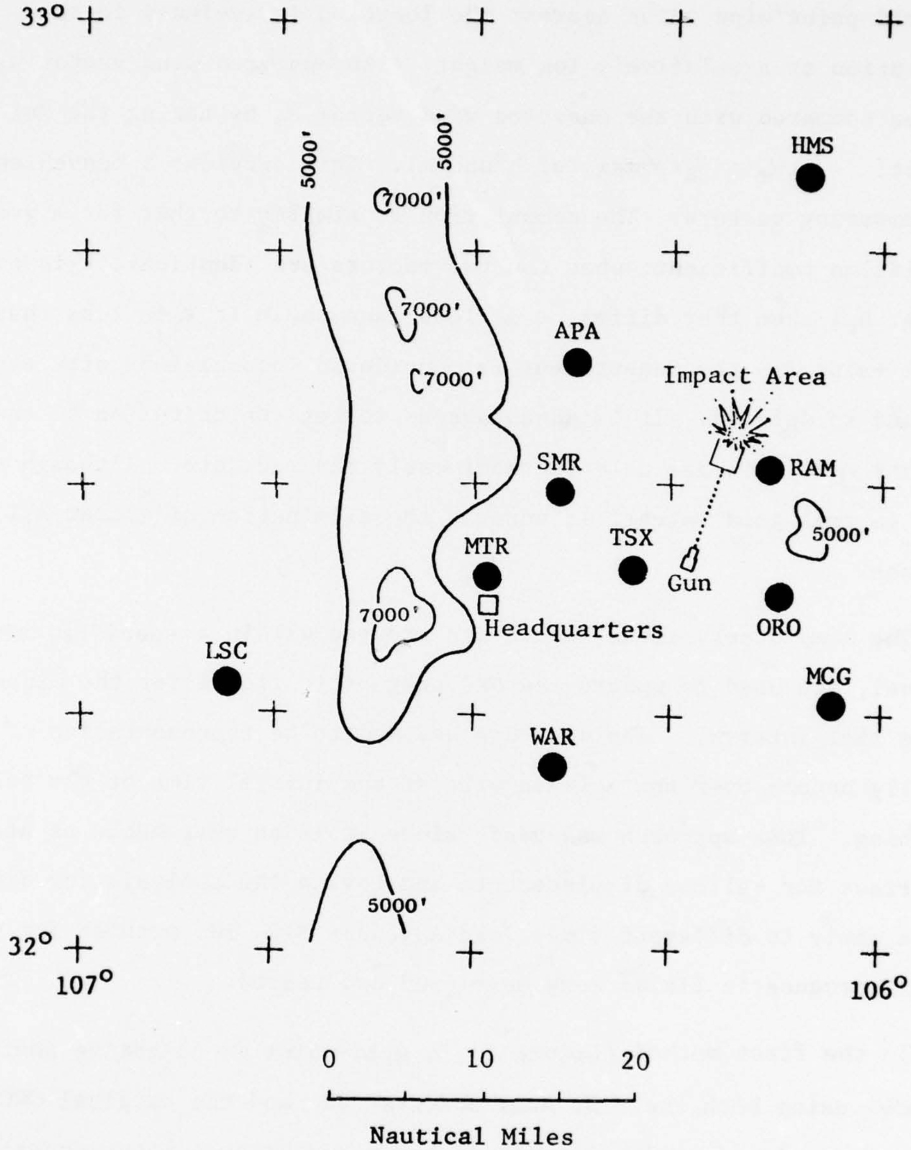

FIGURE 3 U.S. ARMY UPPER-AIR NETWORK FOR THE ARTILLERY METEOROLOGICAL COMPARISONS OF NOVEMBER AND DECEMBER 1974 (MINIGRID OF FIGURE 2 SHOWN BY LATITUDE AND LONGITUDE INDICATOR MARKS, +)

The editing is based principally on surrounding wind data, however, the GWC grid-point wind value nearest the location is included in the computation at a relatively low weight. The analyzed wind vector $\mathbb{V}_a$ is then compared with the measured wind vector $\mathbb{V}_m$ by taking the dot product: $\epsilon = \mathbb{V}_m \cdot \mathbb{V}_a / \mathbb{V}^2 \text{max}$ (of a and m). This provides a convenient form for comparing vectors. The computation is similar to that for a vector correlation coefficient; when the two vectors are identical, ϵ is equal to one, but when they differ, ϵ is less than one. If ϵ is less than some preset value ϵ_c, the measurement is considered inconsistent with other data and is deleted. It is advantageous to set the criterion so that somewhat more data are deleted than merely the bad data. Although this tends to omit good values, it ensures the elimination of almost all the bad ones.

The Army observations, which are grouped within a specified time interval, are used to update the GWC prognostic fields for the midpoint of the time interval. The data are assumed to be representative of what actually occurs over the release site at the initial time of the balloon launching. This approach was used, since it is as reasonable as attempting to correct for balloon displacements and having the analysis for different levels apply to different times (see Appendix B). Two methods for updating the GWC prognostic fields were developed and tested.

In the first method (Update 1), a grid-point or objective analysis is made, using both the U.S. Army observations and the original GWC fields. The new or updated grid-point values are computed by a least-squares fitting of a first-degree polynomial to nearby data. In the least-square fitting, the observations closest to the grid point are given the greatest weighting, and a greater weighting is also given to up- and down-stream

observations than to cross-stream ones; this procedure produces an anisotropic or elliptical-shaped weighting pattern. The initial GWC grid-point value is also included. It is assigned a relatively low weight, so that it will be significant only in areas with no nearby observations. This analysis method has generally given very satisfactory results; it has been described in detail by Mancuso and Wolf (1974) and is also described in Appendix A.

In the second method (Update 2), the GWC minigrid fields of U, V, H, and T are moved an equal amount until they give a best fit to the observed Army observations. The best fit occurs when the normalized mean-squared error for all the fields combined has been minimized. The grid movements are done independently for each level. This method, when tested using the NSSL data, showed large inconsistencies in the results between different levels. Thus, further testing and improvement are required before applying this update method, and it is not currently included in the program options.

When the GWC fields have been updated, a wind field is computed that retains the updated vorticity field but has the original GWC divergence values, using the wind-altering technique of Endlich (1967). The vorticity field is computed from the updated grid-point values of the U and V wind components. The altered winds are then used to compute the balance equation term at each grid point, and these terms are used to compute a balance-height field. Normal-gradient-boundary conditions and an alternating-direction-implicit relaxation method are used to perform this computation of balanced heights (Mancuso, 1967). Results for both the original and the final updated GWC fields are discussed in Section IV-C.

Difference fields between the original and the updated GWC prognostic fields are computed for each level. These difference fields are moved with the GWC pattern trends, using the upwind advection scheme. The advected difference fields are then used to adjust or update the GWC prognoses for later times. Thus, the basic steps of the PDRR computer program are as follows:

- When a new set of GWC analysis and prognostic data (U, V, T, and H) first becomes available, it is used to determine the motion and trends of the weather patterns. This is done by using a pattern-tracking technique.

- The GWC data are interpolated onto a minigrid that is used for performing all the remaining computations. This minigrid is a spherical coordinate grid system that covers the area of military interest.

- U.S. Army rawinsonde data (U, V, T, and H) are used to update the GWC prognostic data. The Army observations are grouped within specified time intervals,* and are treated as sets of data occurring at the midpoint of the time intervals. The observed wind data are checked for errors by comparing each datum with adjacent observations and the nearest GWC value.

- The first observational set of data at time t_1 is used to update the GWC prognostic fields for that same time, as described previously. Difference fields between the original GWC prognostic and the updated fields are computed. These difference fields are moved with the speed and direction computed initially for the GWC patterns and are used to adjust the prognostic field for times later than t_1.

- Second and subsequent sets of Army observational data are similarly used to further update the latest updated GWC fields.

- When a new set of GWC data is received, the above procedure is repeated. However, only the new GWC data are used, and all previous values are purged from the active data base.

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*In the current computer program the time interval within which the Army observations are grouped is set at 40 minutes or ±20 minutes (IDIF=20).

III ARTILLERY APPLICATIONS ROUTINE (AAR)

The purpose of the AAR program is to provide the meteorological information in the form required for artillery firings. The program uses the PDRR output that contains the GWC updated fields on the minigrids. Values of U, V, H, and T at the four GWC levels (surface, 850, 700, and 500 mb) are first interpolated from the GWC updated data for the specific time and location of the firing. A more reasonable profile for each of the four quantities is then constructed that fits the updated GWC values at the four levels, but that retains the shape of the best available observed profile. Figure 4 shows a typical U component profile (solid line) that has been derived by shifting the best available profile (dashed line) to fit updated data that are indicated by an asterisk (*); the derived curve goes through the updated data points. The error quantities, E_i, indicate the difference between the best available profile value and the updated value. The solid curve is obtained by subtracting the error value from the best available values at the GWC levels, and by subtracting a weighted average error value for points in between the GWC levels. The modified profile values are then converted into a Computer Met Message in terms of height zone values for use in computing the artillery corrections. Table 1 shows an example of a Computer Met Message format as used by artillery units.

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*The "best available" is defined as the observation with the lowest Δt, where Δt = (time in minutes between observation and firing) plus (distance in kilometers from gun to observation, divided by 2).

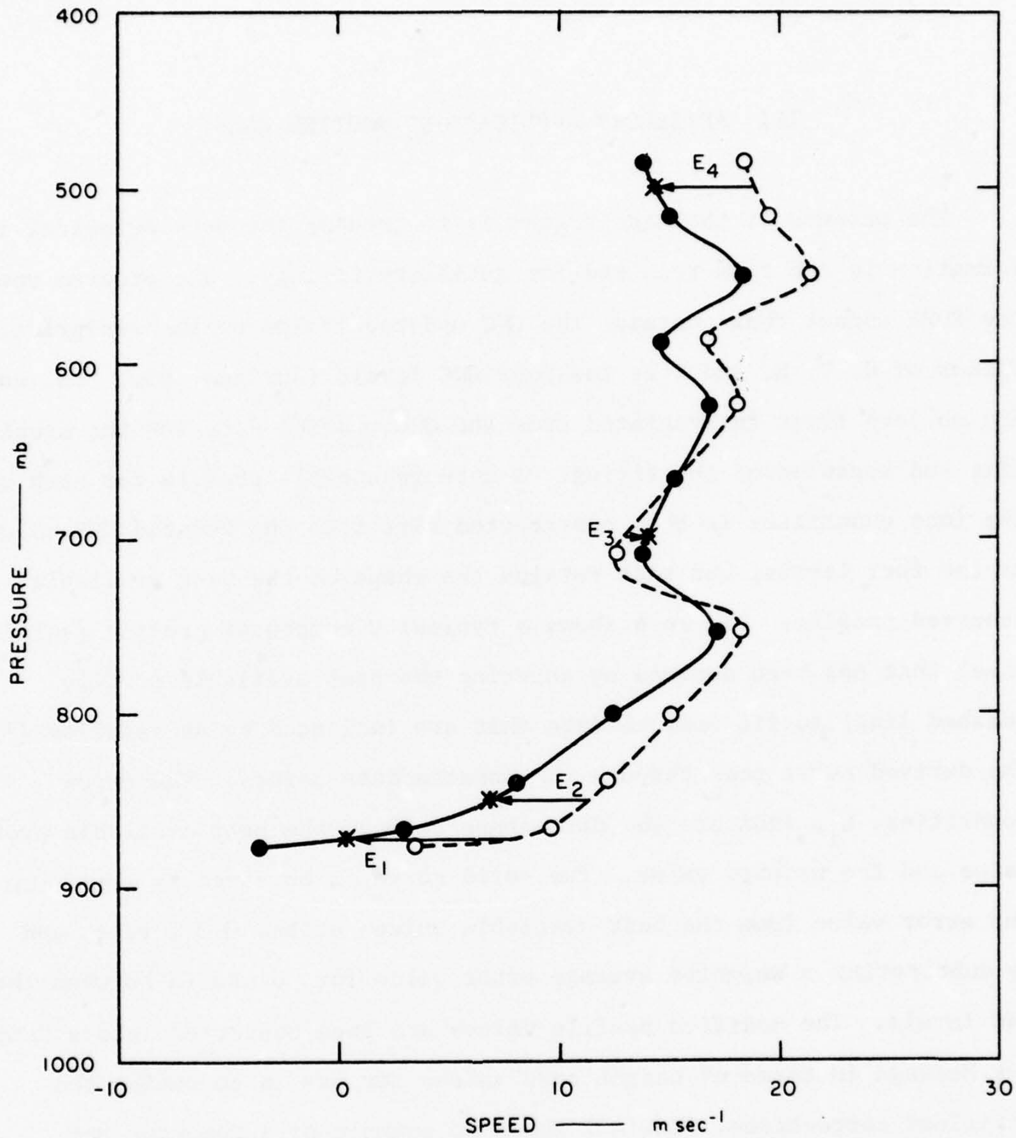

FIGURE 4 SHIFTING OF THE BEST AVAILABLE U COMPONENT PROFILE (DASHED LINE) TO NEW POSITION (SOLID LINE) THAT FITS UPDATED DATA (*); 1230 GMT, 19 NOVEMBER 1974

TABLE 1

COMPUTER MET MESSAGE FOR 1230 GMT

19 November 1974

ZZ (No.)	ddd (10) (mils)	FFF (kts)	TTTT ($1/10^{o}K$)	PPPP (mb)
00	169	007	2890	0876
01	524	007	2888	0866
02	497	016	2881	0840
03	479	024	2842	0801
04	502	034	2800	0753
05	529	029	2757	0708
06	501	030	2734	0666
07	466	033	2709	0625
08	490	029	2689	0587
09	503	036	2670	0550
10	499	029	2638	0516
11	525	030	2595	0484

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IV COMPUTER PROGRAMS

A flow diagram for the PDRR and AAR computer programs is shown in Figure 5. The programs were originally written for a CDC 6400 computer, and FORTRAN listings compatible with that computer are given in Appendices C and D. The programs were modified so that they could be run on the WSMR Univac 1108 computer. These versions of the programs have been given to the Atmospheric Sciences Laboratory of the U.S. Army Electronics Command at WSMR. The programs were designed to be as practical as possible in regard to the data they require and the ease with which they can be modified to incorporate improved products and the results of continuing research. Thus, the programs were organized in the form of several subprograms, and changes can be made with a minimum of disruption of the rest of the program. If future research provides better methods for updating GWC fields, they can be incorporated relatively easily.

A. Data Input for the PDRR Program

The input data card format for the PDRR program is shown in Table 2 with example values. The input data cards provide a convenient way for reading in new values for the control parameters of the program. The input parameters on Card A (ICHK, IANA, IDIV, IBAL, IFOR, IPRINT, and ITAPE) are control parameters that specify whether or not a specific task is to be performed. That is, if the parameter value is set greater than 0, the task is performed; if it is set equal to or less than 0, the task is not performed. Specifically, if ICHK is set greater than 0, then subroutine CHECK is called, and the observed wind values are edited by comparing them with analyzed values for the same locations (if an incon-

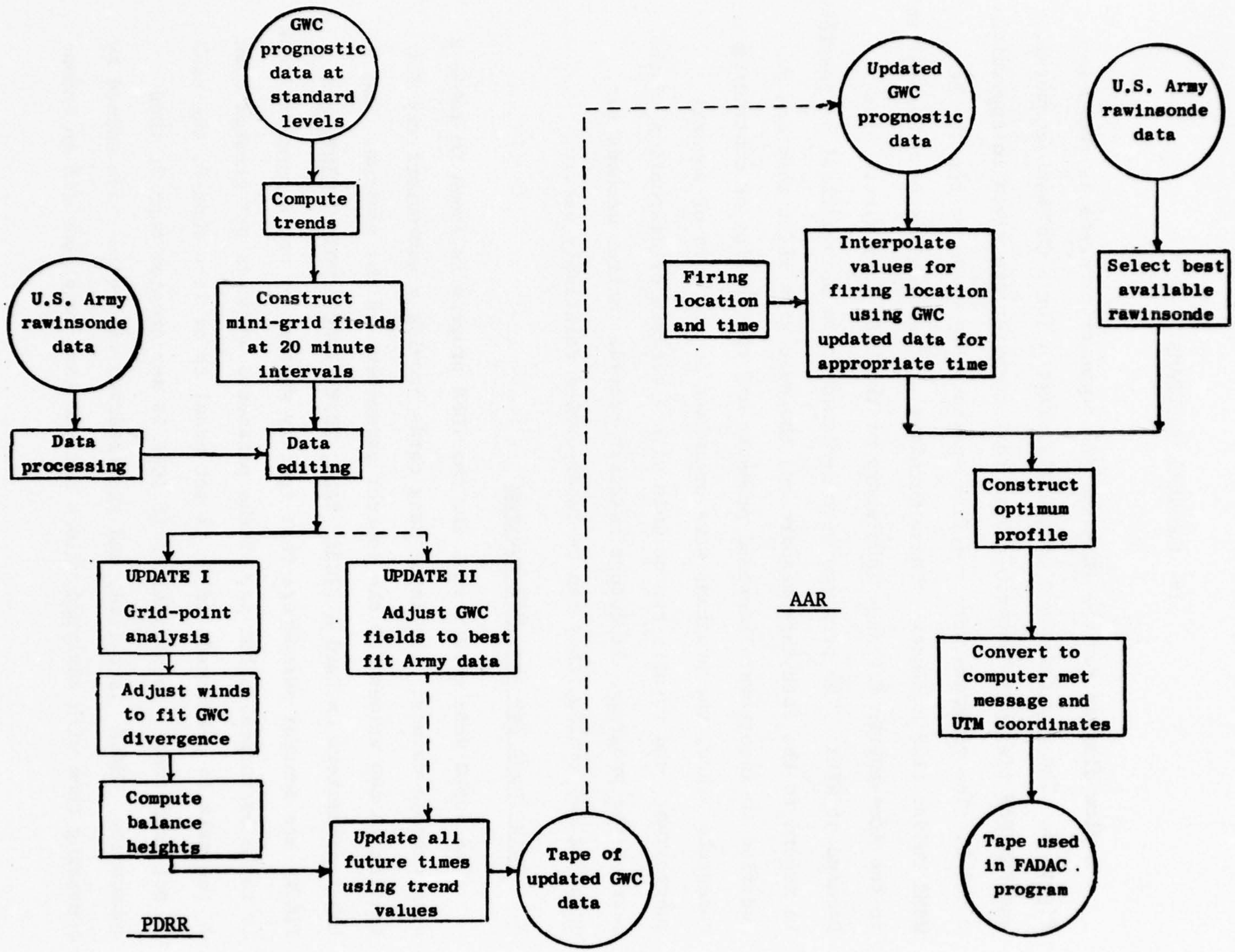

FIGURE 5 FLOW DIAGRAM OF COMPUTER SOFTWARE

Table 2

DESCRIPTION OF THE PARAMETER INPUTS OF THE PDRR PROGRAM WITH EXAMPLE VALUES

Card	Column	Format	Symbol	Units	Value Limits	Typical Value	Description
A	11-20	I10	ICHK	None	[>0 (yes) ≤ 0 (no)]	1 (yes)	Check data for errors in Levels 2,3, and 4
	21-30	I10	IANA	None	["]	1 (")	Analyze Army data with GWC data
	31-40	I10	IDIV	None	["]	1 (")	Make divergence equal to GWC values
	41-50	I10	IBAL	None	["]	0 (no)	Balance heights
	51-60	I10	IFOR	None	["]	1 (yes)	Make forecast
	61-70	I10	IPRINT	None	["]	1 (")	Print output
	71-80	I10	ITAPE	None	["]	1 (")	Tape output
B	11-20	I10	N9	None	>0	7	Number of columns (minigrid)
	21-30	I10	M9	None	>0	7	Number of rows
	31-40	F10.2	XB	Deg	-180 to 180	-106.70	Longitude of upper-left-hand corner of minigrid
	41-50	F10.2	YB	Deg	-90 to 90	32.80	Latitude of upper-left-hand corner
	51-60	F10.2	DD	Deg	>0	0.10	Distance between grid points
	61-70	F10.2	XC	Grid units	1 to 53	15.50	Starting location of left-hand side of section taken from full GWC grid
	71-80	F10.2	YC	Grid units	1 to 57	40.50	Starting location of top of section taken from full GWC grid

Table 2 (Concluded)

Card	Column	Format	Symbol	Units	Value Limits	Typical Value	Description
C	11-20	I10	IT	None	70	1	Number of Army data sets to be used for updating GWC fields
D (I) I=1,IT							IT cards giving the date and midtime (GMT) of data
	15-16	I2	LDATE(1,I)	Yr	0 to 99	74	Year
	17-18	I2	" (2,I)	Mo	1 to 12	11	Month
	19-20	I2	" (3,I)	Day	1 to 31	19	Day
	27-28	I2	" (4,I)	Hr	0 to 24	12	Hour
	29-30	I2	" (5,I)	Min	0 to 60	30	Minutes
E	11-20	I10	JT	None	>0	10	Number of Army upper-air observations
F (J) J=1,JT							JT cards giving the:
	11-20	F10.2	XS(J)	Deg	-180 to 180	-106.32	Longitude of observation
	21-30	F10.2	YS(J)	Deg	-90 to 90	32.40	Latitude of observation
	31-40	F10.2	ES(J)	Meters	0-6000	1230.00	Elevation of observation

sistency is found between an observed and an analyzed wind, the observed wind is deleted). IF IANA is set greater than 0, the Army observed data are analyzed with the GWC data, using Update 1. If IDIV is set greater than 0, the divergence values of the wind fields are made equal to the GWC values. If IBAL is set greater than 0, height fields are computed that are balanced with the wind fields. If IFOR is set greater than 0, forecast fields are generated. The symbols IPRINT and ITAPE are control parameters for the output. If IPRINT is set greater than 0, the output is printed out on the line printer. If ITAPE is set greater than 0, the output is printed on tape.

Card B contains information regarding the size and location of the minigrid array. N9 indicates the number of columns, and M9 indicates the number of rows. XB and YB are the longitude and latitude locations of the upper-left-hand corner of the minigrid, and the symbol DD indicates the distance between the grid points in degrees. A different minigrid is used in the computer example case then that illustrated in Figures 2 and 3. XC and YC establish the upper-left-hand starting location of the 5-by-5 section of the GWC grid. The GWC data is read in from a binary tape on unit 1 in the subroutine GWCIN (Appendix C); using two separate read statements.

Input data are given on Card C for the symbol IT, which represents the total number of Army data sets to be analyzed. Cards D contain the input information for array LDATE, that is, the data and midtime for each of the Army data sets to be used for updating. Although values for only one D card are used in the example case (IT=1), IT may be increased to any desired value; each date/time would then be specified on a separate D card in the same format as shown in Table 2. The Army upper-air data of WSMR is read in from cards by the RAWIN subroutines of both the PDRR and AAR programs (Appendices C and D), using a 10F8.1 format.

Card E is used to designate the number of Army rawinsonde stations (JT) that are being used. Cards F contain input values for the locations and elevations of the total number of stations that are specified on the E card. Each F card contains data for one of the JT stations for the variables XS(J), YS(J), and ES(J), each integer of J representing one of the JT stations. An example of input data for the PDRR program is given in Appendix E.

B. Data Input for the AAR Program

A description of the input data card for the AAR program is given in Table 3 along with example values. Card A contains a list of the various control parameter symbols that are used for printing out labels in the program. Corresponding numerical values for each of the parameters are read in on Card B. The parameter IQ is an indicator that controls what final data are to be printed out. If IQ is 1 or greater, profile curves are plotted out, and a Computer Met Message is printed out in tabulated form. If IQ is less than 1, then only the Computer Met Message is printed out. The variable XFIRE is the longitudinal location of the center of the firing path. The variables XUL, XD, and NX refer to the minigrid. XUL is the longitude of the upper-left-hand corner of the minigrid; XD is the distance in degrees of longitude between the grid points; and NX is the number of grid points in the X direction (longitude). The variable YFIRE is the latitudinal location of the center of the firing path. The variables YUL, YD, and NY also refer to the minigrid. YUL is the latitude of the upper-left-hand corner of the minigrid; YD is the distance in degrees latitude between grid points; and NY is the number of minigrid points in the Y direction (latitude).

Table 3

PARAMETER INPUTS OF THE AAR PROGRAM
WITH EXAMPLE VALUES

Card	Column	Format	Symbol	Units	Value Limits	Typical Value	Description
A	1-80	13A6,A2	ABCDEF	Alpha-meric		IQ,XFIRE, ..	Header label card for data in Card B
B	2	I1	IQ	None	> 0 or $\lesseqgtr 0$	1	Code indicating how data are to be printed > 0: curves and Computer Met Message $\lesseqgtr 1$: Computer Met Message only
	3-10	F8.2	XFIRE	Deg	-180 to 180	-106.23	Longitude of center of firing path
	11-20	F10.2	XUL	Deg	-180 to 180	-106.70	Longitude of upper-left-hand corner of minigrid
	21-25	F5.2	XD	Deg	>0	0.10	Distance between grid points in X (long.)
	26-30	I5	NX	None	>0	7	Number of minigrid array points in X
	43-50	F8.2	YFIRE	Deg	-90 to 90	32.47	Latitude of center of firing path
	51-60	F10.2	YUL	Deg	-90 to 90	32.80	Latitude of upper-left-hand corner of minigrid
	61-65	F5.2	YD	Deg	>0	0.10	Distance between grid points in Y (lat.)
	66-70	I5	NY	None	>0	7	Number of minigrid array points in Y

Table 3 (concluded)

Card	Column	Format	Symbol	Units	Value Limits	Typical Value	Description
C	1-80	13A6,A2	GHIJKL	Alphameric		NT,NL,...	Header label card for data in Card D
D	6-10	I5	NT	None	>0	19	Number of GWC 1-hr forecast times, including initial analysis
	11-15	I5	NL	None	>0	4	Number of GWC levels
	16-25	F10.2	TFCST	Hr(GMT)	0 to 24	0.00	Time of initial analysis of updated GWC data
	26-35	F10.2	TFIRE	Hr(GMT)	0 to 24	12.30	Time of firing
	36-45	I10	IDATE	Yr,Mo,Day	>0	741119	Year, month, and day of GWC initial analyses
	46-55	I10	JSTAT	None	>0	10	Number of Army upper-air observation stations
E	1-80	13A6,A2	MNOPQR	Alphameric		Longitude, ...	Header label card for data in Cards F
F (J)							JSTAT cards giving the:
J=1,JSTAT	11-20	F10.2	XS(J)	Deg	-180 to 180	-106.32	Longitude of station
	21-30	F10.2	YS(J)	Deg	-90 to 90	32.40	Latitude of station
	31-40	F10.2	ES(J)	Meters	> 0	1230.00	Elevation of station

Card C contains a listing of the control parameter symbols for the values given on Card D. The parameter NT of Card D is the number of GWC forecast times, including the initial analysis (NT=19). NL is the number of levels that are available from the updated GWC data (NL=4). TFCST is the time (GMT) of the initial analysis of the GWC data, and TFIRE is the time (GMT) of the artillery firing. IDATE specifies the year, month, and day of the firing. JSTAT is the number of Army observation stations that are used for determining the best available sounding.

Card E contains a listing of the station longitude, latitude, and elevation symbols. Cards F contain values for these variables, that is, XS(J) in degrees longitude, YS(J) in degrees latitude, and ES(J) in meters above sea level; each integer of J represent one of the JT stations. An example input for the AAR program is given in Appendix F.

C. Data Output

The data output from both the PDRR and the AAR programs can be controlled with the IPRINT and ITAPE parameters of Table 2 and the IQ parameter of Table 3. With the PDRR program, detailed line printer outputs, as shown in Appendix G, can be obtained (IPRINT=1), or tape output only can be obtained (IPRINT=0, ITAPE=1). In the print output of the PDRR program, Levels 1, 2, 3, and 4 refer to the surface, 850, 700, and 500 mb. With the AAR program, one can choose to obtain the curves showing the best available and updated profiles, in addition to a Computer Met Message, as shown in Appendix H (IQ=1). If desired, however, only the Computer Met Message need be printed out (IQ=0). The storage requirement of the PDRR program is 23,000 words of memory, and the central processing time for the example used in Appendices E and G is 26 seconds (CDC-6400). The storage requirement of the AAR program is 16,000 words of memory, and the central processing time for the example of Appendices F and H is 12 seconds.

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V SUMMARY AND RECOMMENDATIONS

A method for providing meteorological information for artillery has been developed in this study and implemented as the PDRR and AAR computer programs. The first of these programs uses artillery upper-air observations to update GWC prognostic fields. The second generates atmospheric zone values of wind, temperature (virtual), and pressure for the Computer Met Message, on the basis of updated GWC fields and the best available rawinsonde profile. These programs provide a versatile and general method for supplying meteorological information to the artillery, and would be particularly applicable where extrapolation is required in either time or space. The method uses the current numerical products of GWC, which are based on a baroclinic prediction model. However, forecast should eventually be based on a primitive equation (PE) model, which would use smaller grid spacing and more levels. Also, a mesoscale forecasting model has been developed by the U.S. Air Force (Kaplan, 1972). Results from either of these would be more appropriate to use as the basic fields to be updated with the Army observations and should lead to substantial improvements. This would be particularly important for providing more accurate surface forecasts over terrain such as White Sands. If either of the above-mentioned types of models are made operational by GWC, the PDRR and AAR programs should be modified to use the new products. Other recommendations for refining the programs are:

- Optimize parameters, and compare different options of the Prognostic Data Reanalysis Routine (PDRR) and the Artillery Application Routine (AAR).

- Develop and test improved analysis techniques, including the incorporation of terrain influence.

The testing and development could be carried out by using the entire set of the ASL Artillery Meteorological Comparisons data from November and December 1974. The actual artillery firing results that were obtained concurrently with the upper-air observations could be used to verify the meteorological analyses. These refinements of the programs could lead toward a fully automated meteorological service that would be both accurate and versatile, as required for military operations (ASL, 1973). Significant progress should be possible because of the availability of the Artillery Meteorological Comparisons data and the current ASL software such as described in this report.

Appendix A

OBJECTIVE ANALYSIS

The fitting of a polynomial surface to observations adjacent to a grid point is a natural approach for interpolating a grid-point value. Schemes based on this approach have been used by a number of investigators, one of the earliest being Gilchrist and Cressman (1954). In the objective analysis described in this appendix, a grid-point value for a quantity is obtained by a least-squares fit of a first-degree polynomial surface to adjacent observational values. In the least-squares fitting, the observations are weighted inversely with distance. Upstream and downstream observations are given greater weight than cross-stream observations. This anisotropic weighting produces an elliptical field of weights, with the long axis in the direction of flow; it is particularly desirable when analyzing such phenomena as jet streams. Sasaki (1971) showed by the variational method that such weighting is theoretically consistent with the advection terms in the equations of motion. The basic objective analysis was originally developed for analyzing surface and upper-air data over the United States (Endlich and Mancuso, 1968). It has since been modified to allow for more general applications (Endlich and Mancuso, 1973).

The actual objective analysis procedure follows: A grid-point value for a quantity is determined by fitting a first-degree polynomial surface by least squares to K nearby observations. An optimum fit is obtained by minimizing

$$Q = \sum_{1}^{K} w(q - \hat{q})^2 \quad ,$$

where w is a weighting factor, q is an observed value at some location (x,y), and $\hat{q}$ is the polynomial estimate for the same location (a + bx + cy). If an initial guess value for a grid point is provided, it is treated as the first observational value (K = 1) and is given a fixed weight w_1. A relatively low value is normally assigned to w_1, so the initial estimate will have a significant influence only in areas where there are no nearby data. The remaining K - 1 observations are normally those nearest the grid point. However, it is required, if possible, that at least one observation be selected from each of the four angular quadrants (0-90, 90-180, 180-270, and 270-360 degrees). This tends to keep the analysis continuous in regions of poorly distributed data and large gaps. The value used for K has varied between 5 and 10; the higher value is used in areas of unevenly distributed data.

The weighting for an observation is given by

$$w = C^2/[C^2 + R^2 + (\alpha S)^2]$$

$$S \equiv (\mathbb{k} \cdot \mathbb{R} \times \mathbb{V})/ |\mathbb{V}| \quad .$$

The R in this equation represents the magnitude of the horizontal distance vector ($\mathbb{R}$) between the grid point and the observation. Thus, the closer an observation is to the grid point, the greater the weighting. The degree of this effect is dependent on the value assigned to the constant C. The S in the above equation is included to give a greater weighting to upstream and downstream observations than to cross-stream observations, at equal distances. This produces the anisotropic weighting pattern mentioned previously. The control parameter α is included so that the relative influence of the anisotropic weighting can be varied.

The result obtained by fitting a second-degree polynomial surface to distance-weighted U and V component data at 300 mb over the United States is shown in Figure A-1(a). This figure shows the isotachs that were drawn to the computed wind speed values at the grid points spaced every 2.5 degrees of latitude and longitude (the results for wind direction are not shown). The figure also shows the basic wind data in vector form. The isotach field that was obtained from a direct hand analysis of wind speeds is shown in Figure A-1(b). There are some noticeable differences between these two fields [Figure A-1(a) and (b)], and the rms difference is 3.5 m sec^{-1}. These differences are due in large part to the fact that the polynomial analysis was based on U and V wind component data, while the hand analysis was made directly from wind speed data.

Figure A-1(c) shows the isotach field obtained by fitting a first-degree polynomial surface to distance-weighted U and V wind component data, both including and excluding the anisotropic weighting effect. A closer fitting of the nonlinear features is obtained by using the second-degree polynomial [Figure A-1(a)]. However, the use of higher-order polynomials requires more computation time and complex programming. Although the overall rms difference between the analyses depicted in Figure A-1(c) is not large (1.3 m sec^{-1}), the inclusion of the anisotropic weighting does produce a desirable streakiness in jet stream areas and a better fit to the nonlinear features.

Figure A-1(d) shows the isotach field obtained when a first-degree polynomial surface was fitted directly to wind speeds, as opposed to fitting the U and V components; in both cases, optimum weighting values were used ($C^2 = 2$ and $\alpha = 2.5$). A very good agreement with the hand analysis

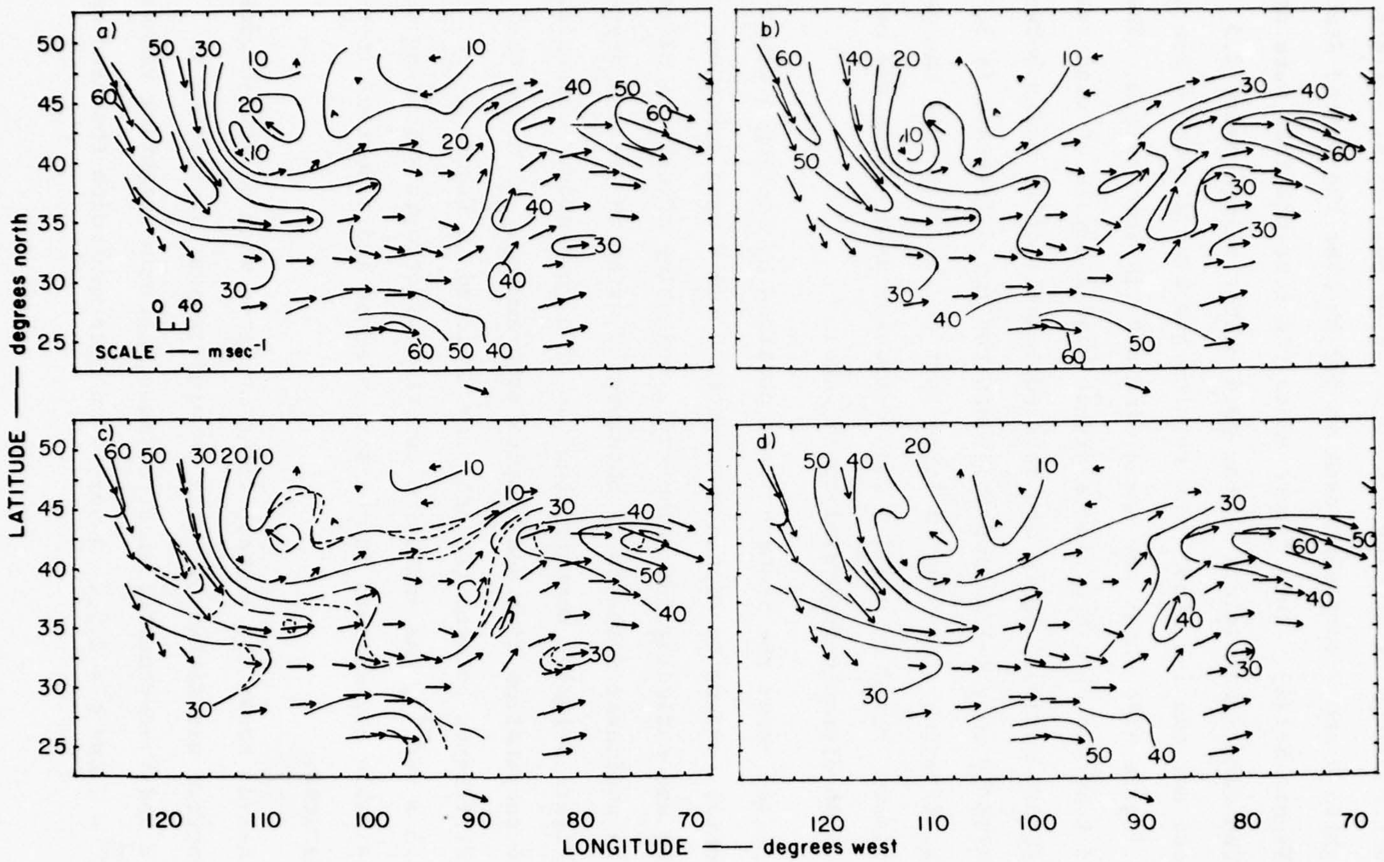

FIGURE A-1 ISOTACHS SHOWING DIFFERENT ANALYSES OF WIND SPEED (m sec^{-1}) THAT WERE OBTAINED USING 300 mb WIND OBSERVATIONS (SHOWN BY VECTORS) OVER THE UNITED STATES; 0000 GMT, 18 MARCH 1972

Analyses were obtained by: (a) second-degree polynomial fit to u and v wind components; (b) hand analysis of wind speeds; (c) first-degree polynomial fit to u and v components, both excluding (short dashed lines) and including (long dashed lines) anisotropic weighting (solid lines are used where results are the same); and (d) first-degree polynomial fit to wind speeds.

shown in Figure A-1(b) was obtained in this way (rms difference = 3.0 m sec^{-1}). However, the results obtained by fitting the U and V wind components [Figure A-1(c)] are in better agreement with the second-degree polynomial analysis of Figure A-1(a) (rms difference 3.5 $msec^{-1}$), than with the hand analysis of Figure A-1(b) (rms difference = 4.0 $msec^{-1}$).

The weighting parameters C and α are determined experimentally to optimize the results. A better fit to nonlinear features occurs as C is decreased, but little improvement occurs when C is reduced excessively. The distance weighting is important; if it is not incorporated or if C is set too high, the analysis is overly smoothed. However, some smoothing is desirable because of data errors and to produce a more continuous field. Thus, the value of C is usually not set too low, but is generally set less than the value of the grid spacing. Figure A-2 shows the rms difference of a first-degree polynomial analysis relative to both a hand and a second-degree polynomial analysis as a function of α (C^2 = 2). A definite minimum in the differences occurs when the anisotropic weighting parameter α is set at a value between 2 and 3. Although the anisotropic weighting effect is not as strong as the distance weighting effect, it does produce important differences in critical regions, as shown in Figure A-1(c), and is easily incorporated into the analysis scheme.

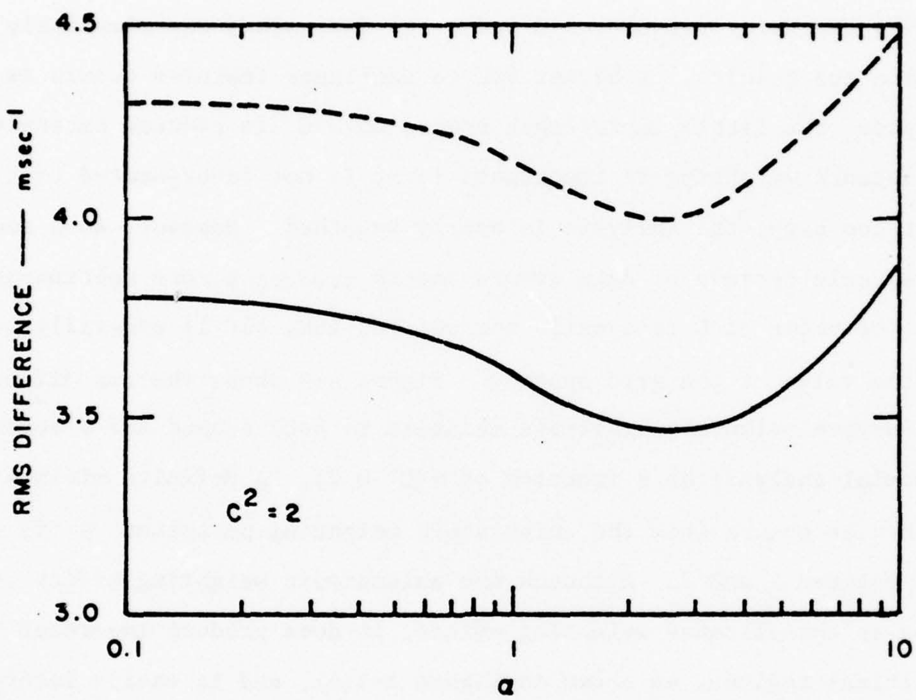

FIGURE A-2 RMS WIND SPEED DIFFERENCES BETWEEN FIRST- AND SECOND-DEGREE POLYNOMIAL ANALYSES (SOLID LINE) AND BETWEEN FIRST-DEGREE POLYNOMIAL AND HAND ANALYSES (DASHED LINE)

Appendix B

SIGNIFICANCE OF BALLOON DISPLACEMENTS

The rawinsonde balloon displacements from the release sites are normally not considered in conventional synoptic-scale analyses. The displacement of the balloon at a height H will be given by $D \simeq \bar{V} t$, where $\bar{V}$ is the average speed between the surface and H, and t is the time it took the balloon to rise to H. In analyses over the United States, D would be at most about 60 miles at high altitudes (10 km) and high winds (100 $msec^{-1}$), and would normally be less than 30 miles. However, in mesoscale analyses, it becomes a more important question, since the horizontal resolution becomes less than 60 miles. The approximate spacing between stations for various mesoscale networks is given below.

Thunderstorm Project 1947 (Fujita, 1958)	5-10 miles
NSSL 1966/1967 (Barnes et al, 1971)	50 miles
WSMR Oct/Nov 1974 (ASL, 1974)	10-20 miles

A three-dimensional illustration of balloon displacements is shown in Figure B-1 for the Thunderstorm Project. The displacements are quite significant, and for an accurate analysis they would need to be taken into account.

Two approaches are possible for handling the balloon displacement problem:

- Correct the location according to a calculated displacement with increasing height, assuming some constant balloon rate of rise such as 5.5 $msec^{-1}$. The analyses at the higher levels would have to be applied to slightly later times.

- Assume that a hindcast can be made by simply advecting the winds backward in time, using the average wind value from the surface up to the level in question. Thus, no correction of locations would be required; that is, the measured wind value would be allowed to apply to the location and time of the release.

The second approach is the easier to adopt, since it requires no corrections. Its merit depends on the validity of the hindcast. When corrections are most needed, as in strong wind conditions, it would probably have less merit. This approach is currently being used in the PDRR program; however, further testing should be carried out to compare the two approaches, using the WSMR November and December 1974 comparison data.

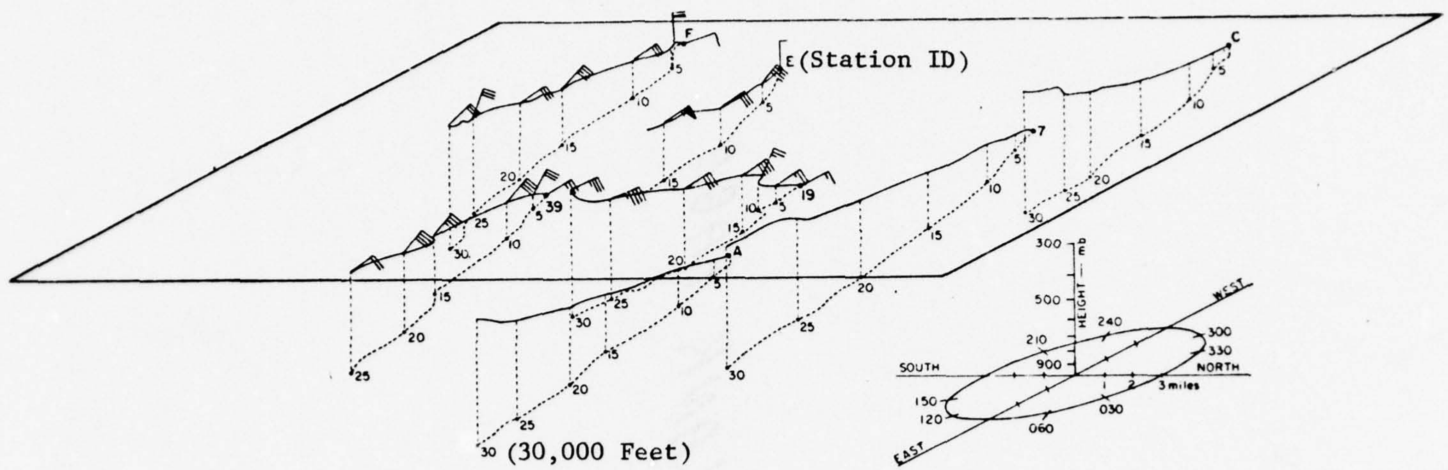

FIGURE B-1 THREE-DIMENSIONAL VIEW OF BALLOON DISPLACEMENTS FROM THE THUNDERSTORM PROJECT; 1445 EST, 11 JUNE 1947 (PREPARED BY ROY BLACKMER OF SRI)

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Appendix C

PDRR PROGRAM

LISTING

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```
      PROGRAM   PDRR(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,PUNCH)
C
C THIS PROGRAM IS THE PROGNOSTIC DATA REANALYSIS ROUTINE (PDRR). IT IS
C  USED FOR REANALYZING OR UPDATING THE GLOBAL WEATHER CENTER (GWC)
C  PROGNOSTIC DATA USING THE MOST RECENTLY AVAILABLE ARMY UPPER AIR
C  OBSERVATIONS.
C
C DIMENSION AND COMMON STATMENTS
C
      INTEGER DATA(12000)
      DIMENSION U(100),V(100),H(100),T(100),VOR(100),DIV(100),BAL(100)
      DIMENSION US(25),VS(25),HS(25),TS(25),XS(25),YS(25),ES(25)
      DIMENSION X(10),Y(10),DSX(100),DSY(100),LDATE(5,25),IMD(12)
      DIMENSION CM(10),TM(10),TRU(100),TRV(100)
      DIMENSION DAT1(400),GAT1(100),GAT2(100),VAT(25),WAT(25),GAS(100,4)
      DIMENSION UR(100),VR(100),HR(100),TR(100)
      COMMON/CIS/ IS(1000)
      COMMON/CCHK/ CRT,SIM,GIM,IWND
      COMMON/CGD/ M9,N9,I9,M8,N8,YB,XB,DD
      COMMON/CPTS/    KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      EQUIVALENCE (U,GAS(1,1)),(V,GAS(1,2)),(H,GAS(1,3)),(T,GAS(1,4)),
     2            (UR,DAT1(1)),(VR,DAT1(101)),(HR,DAT1(201)),
     3            (TR,DAT1(301)),(VOR,DSX),(DIV,DSY)
C
C SET BASIC CONSTANTS (INITIALLY SET CORE TO ZERO)
C
      DATA IDIF,IGMT /20,-420/
      DATA I0,I1,I2/0,1,2/
      DATA CRT,SIM,GIMS,IWND/0.3,0.1,0.05,1/
      DATA  NVARP,NSIZE /2,5/
      DATA W1,C2,RMAX,KS,KSS5,KSW,IDS,ALPH/0.10,0.02,10.0,10,5,0,1,2.0/
      DATA I20,L1,L4,L100,K4,N5,N25 /19,1,4,100,4,5,25/
      DATA XP,YP,ROT,DTS,ACR/24.0,26.0,80.0,1.0,0.0174533/
      DATA  IMD/0,31,59,90,120,151,181,212,243,273,304,334/
    1 FORMAT(10X,7I10)
    2 FORMAT(10X,2I10,5F10.2)
    3 FORMAT(10X,I10)
    4 FORMAT(14X,3I2,6X,2I2)
    5 FORMAT(10X,I10)
    6 FORMAT(10X,3F10.2)
    7 FORMAT(2X,6I10,2E15.3)
C
C READ IN CONTROL PARAMETERS
C
      READ 1, ICHK,IANA,IDIV,IBAL,IFOR,IPRINT,ITAPE
      READ  2,N9,M9,XB,YB,DD,XC,YC
      READ 3,IT
      READ 4,((LDATE(L,I),L=1,5),I=1,IT)
      READ 5,JT
      READ 6,    (XS(J),YS(J),ES(J),J=1,JT)
C
C PRINT OUT CONTROL PARAMETERS
C
      PRINT 9000
      PRINT 9100
```

```
      PRINT 9000
      PRINT 9050
      PRINT 9001,ICHK,IANA,IDIV,IBAL,IFOR,IPRINT,ITAPE
      PRINT 9002,N9,M9,XB,YB,DD,XC,YC
      PRINT 9003,IT
      PRINT 9054
      PRINT 9004,((LDATE(L,I),L=1,5),I=1,IT)
      PRINT 9005,JT
      PRINT 9056
      PRINT 9006,(J,XS(J),YS(J),ES(J),J=1,JT)
C
C PERFORM BASIC COMPUTATIONS
C
      IF (IT.GT.25.OR.JT.GT.25) GO TO 999
      IF (M9.GT.10.OR.N9.GT.10) GO TO 999
      GIM=GIMS
      IH20=(I20-1)*60
      X100=DTS*60.0
      I9=M9*N9
      M8=M9-1
      N8=N9-1
      N49=I9
      N98=N49+N49
      N47=N98+N49
      K3=K4-1
      ID=L4*K3*N49
      DO 20 N=1,N9
   20 X(N)=XB+DD*(N-1)
      XAVE=ACR*(-X(N5)-ROT)
      SAVE=SIN(XAVE)
      CAVE=COS(XAVE)
      DO 22 M=1,M9
      Y(M)=YB-DD*(M-1)
      ANG=ACR*Y(M)
      CM(M)=COS(ANG)
   22 TM(M)=TAN(ANG)
      XN5=-X(N5)
      CGD=1.0+Y(N5)/90.0
      I=0
      DO 24 M=1,M9
      TLA=TAN((90.0-Y(M))*ACR*0.5)*31.2042
      DO 24 N=1,N9
      I=I+1
      XLO=ACR*(-X(N)-ROT)
      DSX(I)=(XP-TLA*SIN(XLO)-XC)*2.0+1.0
   24 DSY(I)=(YP+TLA*COS(XLO)-YC)*2.0+1.0
C
C LOOP THROUGH ALL GWC FORECASTING TIMES
C
      DO 50 IG=1,I20
C
C READ IN GWC DATA
C
      CALL GWCIN(IG,IGWC,JDATE,JTIME,DAT1,IMD)
      DO 45 L=L1,L4
      N1=(L-1)*L100
```

```
      IP=((IG-1)*L4+L-1)*I9*K3
      JP=0
      DO 42 K=1,K4
      IF (K.EQ.K4) IP=IP-N49
      DO 36 N=1,N25
      N1=N1+1
      DATN=DAT1(N1)
      WAT(N)=DATN
      IF (K.GT.2) GO TO 35
      N3=N1
      IF (K.EQ.2) N3=N1-N25
      DATN=DAT1(N3)
      VATN=DAT1(N3+N25)
      WAT(N)=DATN
      IF (K.EQ.2) WAT(N)=VATN
      CALL UVCONV(DATN,VATN,-X(N5))
      IF (K.EQ.2) DATN=VATN
   35 JP=JP+1
      GAT1(JP)=GAS(JP,L)
      GAS(JP,L)=DATN
      GAT2(JP)=DATN
   36 VAT(N)=DATN
      DO 40 I=1,I9
      DLX=DSX(I)
      DLY=DSY(I)
      NX=INT(DLX)
      MY=INT(DLY)
      NM=(MY-1)*N5+NX
      DLX=DLX-NX
      DLY=DLY-MY
C
C INTERPOLATE TO MINI GRID
C
      CALL INTPT(NM,N5,VAT,DLX,DLY,BAT)
      IP=IP+1
      IBAT=INT(BAT*10.0)
      IF (K.EQ.3) IBAT=IBAT*10000
      IF(K.NE.4) GO TO 40
      IF(DATA(IP).LT.0) IBAT=-IBAT
      IBAT=DATA(IP)+IBAT
   40 DATA(IP)=IBAT
   42 CONTINUE
C
C COMPUTE TRENDS
C
      IF (IFOR.LT.1.OR.IG.LT.2) GO TO 45
      LIG=(IG-1)*L4+L
      NVARS=NVARP
      IF (L.EQ.1) NVARS=NVARP-1
      CALL TREND(NVARS,NSIZE,TRU(LIG),TRV(LIG),GAT1,GAT2,IG)
      TRU(LIG)=TRU(LIG)*CGD
      TRV(LIG)=-TRV(LIG)*CGD
      CALL UVCONV(TRU(LIG),TRV(LIG),XN5)
      TRU(LIG)=TRU(LIG)/DD
      TRV(LIG)=TRV(LIG)/DD
      IF (ABS(TRU(LIG)).GT.5.0) TRU(LIG)=SIGN(5.0,TRU(LIG))
```

```
      IF (ABS(TRV(LIG)).GT.5.0) TRV(LIG)=SIGN(5.0,TRV(LIG))
   45 CONTINUE
   50 CONTINUE
C
C END OF GWC LOOP
C
      PRINT 2,JP,IP
      IF (IANA.LT.1) GO TO 101
C
C LOOP THROUGH ARMY RAWINSONDE OBSERVATION TIMES
C
      DO 100 IR=1,IT
      I=IR
      LD2=LDATE(2,I)
      IDATE=LDATE(5,I)+60*(LDATE(4,I)+24*(LDATE(3,I)+IMD(LD2)
     2        +365*LDATE(1,I)-366))
      PRINT 1,IGWC,IDATE
      IF (IDATE.LT.IGWC) GO TO 999
      IF (IDATE.GT.IGWC+IH20) GO TO 999
      ICOMP=IGWC+X100
      DO 60 IG=2,I20
      IF (IDATE-ICOMP) 58,60,60
   58 FG2=(ICOMP-IDATE)*0.1/X100
      FG1=0.1-FG2
      GO TO 61
   60 ICOMP=ICOMP+X100
      GO TO 999
   61 IG=IG-1
      IL=(IG-1)*ID
      PRINT 1,ICOMP,IDATE,IG
      PRINT 6,FG1,FG2
C
C READ IN RAWINSONDE DATA
C
      CALL RAWIN(JT,IR,ES,UR,VR,HR,TR,IMD,IDATE,IDIF,IGMT)
C
C LOOP THROUGH MANDATORY LEVELS
C
      DO  95 L=L1,L4
      LJ=(L-1)*JT
      DO 68 J=1,JT
      US(J)=UR(J+LJ)
      VS(J)=VR(J+LJ)
      HS(J)=HR(J+LJ)
   68 TS(J)=TR(J+LJ)
      N1=IL+(L-1)*N49*K3+1
      N2=N1+N49-1
      I=1
      DO 70 N=N1,N2
      U(I)=DATA(N)*FG1+DATA(N+ID)*FG2
      V(I)=DATA(N+N49)*FG1+DATA(N+N49+ID)*FG2
      IH1=INT(DATA(N+N98    )*0.0001)
      IH2=INT(DATA(N+N98+ID)*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT2=DATA(N+N98+ID)-IH2*10000
      IT1=IABS(IT1)
```

```
      IT2=IABS(IT2)
      H(I)= IH1*FG1+IH2*FG2
      T(I)= IT1*FG1+IT2*FG2
   70 I=I+1
      PRINT 9000
      PRINT 9059,L
      IF (ICHK.LE.0.OR.L.EQ.1)  GO TO 170
      CALL MESH(I0,JT,YS,XS,VS,US,HS,TS,Y,X,V,U,H,T)
                               CALL CHECK(JT,YS,XS,VS,US,Y,X,V,U)
  170 IF (IPRINT.LT.1) GO TO 71
      PRINT 9025
      PRINT 9057
      PRINT 9007,(J,HS(J),TS(J),US(J),VS(J),J=1,JT)
      PRINT 9000
      PRINT 9060
      PRINT 9062
      PRINT 9010,(H(I),I=1,I9)
      PRINT 9064
      PRINT 9010,(T(I),I=1,I9)
      PRINT 9066
      PRINT 9010,(U(I),I=1,I9)
      PRINT 9068
      PRINT 9010,(V(I),I=1,I9)
   71 CONTINUE
      IF (IANA-1) 85,73,72
   72 CONTINUE
      GO TO 85
   73 DO 173 I=1,I9
      VOR(I)=0.0
      DIV(I)=0.0
  173 BAL(I)=0.0
      CALL KID(I0,I1,I0,VOR,DIV,BAL,U,V,CM,TM)
      CALL MESH(I0,JT,YS,XS,VS,US,HS,TS,Y,X,V,U,H,T)
      CALL MESH(I2,JT,YS,XS,VS,US,HS,TS,Y,X,V,U,H,T)
      IF (IDIV.LT.1) GO TO 75
C
C ADJUSTMENT OF WIND FIELD TO THE GWC DIVERGENCE FIELD
C
      CALL KID(I1,I1,I0,VOR,BAL,DIV,U,V,CM,TM)
      CALL ALTERS(25,0.0,0.5,TM, CM, U,V,VOR,DIV)
   75 IF (IBAL.LT.1) GO TO 85
C
C COMPUTATION OF BALANCED HEIGHT FIELD
C
      CALL KID(I1,I1,I1,VOR,DIV,BAL,U,V,CM,TM)
      SUM=0.0
      DO 80 I=1,I9
   80 SUM=SUM+H(I)
      AVE=SUM/I9
      CALL  BALHGT(M9,N9,YD,1,15,1.2,.01,AVE,CM,TM,H,BAL)
   85 CONTINUE
      IF (IPRINT.LT.1) GO TO 86
      PRINT 9000
      PRINT 9070
      PRINT 9062
      PRINT 9010,(H(I),I=1,I9)
```

```
      PRINT 9064
      PRINT 9010,(T(I),I=1,I9)
      PRINT 9066
      PRINT 9010,(U(I),I=1,I9)
      PRINT 9068
      PRINT 9010,(V(I),I=1,I9)
   86 CONTINUE
      IF (IFOR.LT.1) GO TO   95
C
C UPDATE ALL GWC FORECAST FIELDS BY ADVECTING WITH COMPUTED TRENDS
C
      DO 90 IH=IG,I20
      N1=(IH-1)*ID+(L-1)*K3*N49+1
      N2=N1+N49-1
      DT=DTS
      LIH=(IH-1)*L4+L
      IF (IH.GT.IG) GO TO 88
      DT=-FG1*10.0*DT
      I=1
      DO 87 N=N1,N2
      U(I)=DATA(N)*FG1+DATA(N+ID)*FG2-U(I)
      V(I)=DATA(N+N49)*FG1+DATA(N+N49+ID)*FG2-V(I)
      IH1=INT(DATA(N+N98    )*0.0001)
      IH2=INT(DATA(N+N98+ID)*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT2=DATA(N+N98+ID)-IH2*10000
      IT1=IABS(IT1)
      IT2=IABS(IT2)
      H(I)= IH1*FG1+IH2*FG2-H(I)
      T(I)= IT1*FG1+IT2*FG2-T(I)
   87 I=I+1
   88 LIH=(IH-1)*L4+L
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),U,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),V,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),H,BAL,CM)
      CALL ADVEC(DT,TRU(LIH),TRV(LIH),T,BAL,CM)
      I=1
      DO 89 N=N1,N2
      DATA(   N)=DATA(   N)-U(I)*10
      DATA(N+N49)=DATA(N+N49)-V(I)*10
      IH1=INT(DATA(N+N98    )*0.0001)
      IT1=DATA(N+N98    )-IH1*10000
      IT1=IABS(IT1)
      IH2=IH1-H(I)*10.0
      IT2=IT1-T(I)*10.0
      IF(IH2.LT.0) IT2=-IT2
      DATA(N+N98)=IH2*10000+IT2


   89 I=I+1
   90 CONTINUE
   95 CONTINUE
C
C END OF LEVEL LOOP
C
C
```

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```
C WRITE OUT UPDATAD FIELDS ON TAPE3
C
      IF (ITAPE.LT.1) GO TO 100
      WRITE (3) JDATE,JTIME
      DO 98 IH=1,I20
      DO 98 L=L1,L4
      N1=(IH-1)*ID+(L-1)*K3*N49+1
      N2=N1+N49-1

   98 WRITE (3) (DATA(N),DATA(N+N49),DATA(N+N98),N=N1,N2)
  100 CONTINUE
C
C END OF ARMY LOOP
C
  101 CONTINUE
      GO TO 1000
  999 PRINT 9999
 1000 CONTINUE
 9000 FORMAT(1H1)
 9001 FORMAT(2X,8HCARD A  ,7I10//)
 9002 FORMAT(2X,8HCARD B  ,2I10,5F10.2//)
 9003 FORMAT(2X,8HCARD C  ,I10//)
 9004 FORMAT(8X,5I10/)
 9005 FORMAT(/2X,8HCARD E  ,I10,//)
 9006 FORMAT(10X,I5,5X,3F10.2/)
 9007 FORMAT(16X,I2,2X,4F10.2)
 9010 FORMAT(    10X,7F5.0)
 9025 FORMAT(1H )
 9050 FORMAT(30X,27HINPUT DATA FOR PDRR ROUTINE///)
 9054 FORMAT(2X,57HCARDS D       YEAR      MONTH          DAY       HOUR
    2 MIN/)
 9056 FORMAT(2X,8HCARDS F ,9X,20HSTATION  INFORMATION//12X,10HNUMBER
    2      ,30HLONGITUTE  LATITUTE  ELEVATION/)
 9057 FORMAT(25X,13HSTATION  DATA// 9X,33H       NUMBER  D VALUE  TEMPERAT
    2URE,    19H  U COMP     V COMP ,/)
 9059 FORMAT(10X,22HRESULTS FOR LEVEL L = ,I1//)
 9060 FORMAT(20X,21HGWC DATA ON MINI GRID//)
 9062 FORMAT(/24X,8HD VALUES/)
 9064 FORMAT(/23X,11HTEMPERATURE/)
 9066 FORMAT(/26X,6HU COMP/)
 9068 FORMAT(/26X,6HV COMP/)
 9070 FORMAT(15X,29HUPDATED GWC DATA ON MINI GRID//)
 9100 FORMAT(///45X,34HPROGNOSTIC DATA REANALYSIS ROUTINE,//////
    2///,    57X,5HUNITS,///,53X,11HSPEED - MPS,//,53X,15HDIRECTION - DE
    3G,//,   53X,15HHEIGHT - METERS,//,53X,19HTEMPERATURE - DEG K)
 9999 FORMAT(10X,23HINCONSISTENT INPUT DATA)
      STOP
      END
```

```
      SUBROUTINE GWCIN(I,IGWC,JDATE,JTIME,DAT1,IMD)
C
C THIS SUBROUTINE READS IN THE GWC FORECAST DATA.
C
C  I = HOUR INDEX--I EQUALS 1 FOR INITIAL ANALYSIS TIME AND I EQUALS 5
C                  FOR FORECAST 4 HOURS AFTER INITIAL ANALYSIS
C  IGWC = AD TIME IN MINUTES--COMPUTED IN SUBROUTINE
C  DAT1 = ARRAY CONTAINING GWC DATA
C  IMD = NUMBER OF DAYS FROM BEGINING OF YEAR UP TO MONTH INDICATED
C        BY INDEX
C
      DIMENSION IAT(600),IPRE(5),PRS(5)
      DIMENSION DAT1(1),IMD(1)
      DATA RH /50.0/
      DATA L1,L4,K4,N25,L100/1,4,4,25,100/
      DATA (PRS=870.0,850.0,700.0,500.0,300.0)
      IF (I.GT.1) GO TO 10
      READ (1) ND,(IPRE(N),N=1,5)
      PRINT 1,IPRE(2),IPRE(3),IPRE(4),IPRE(1)
    1 FORMAT(10X,42HGWC FORECAST DATA READ IN FOR ANALYSIS OF ,I5,1H/,I2
     2         ,1H/,I2,5X,I5,4H GMT//)
      IPRE1=INT(IPRE(1)*0.01)
      IPRE3=IPRE(3)
      IGWC=IPRE(1)-IPRE1*40+1440*(IPRE(2)+IMD(IPRE3)+365*IPRE(4)-366)
      JDATE=IPRE(4)*10000+IPRE(3)*100+IPRE(2)
      JTIME=IPRE(1)
   10 READ (1) IAT
      IN=0
      DO 20 L=L1,L4
      LT=(L-1)*N25
      DO 20 K=1,K4
      LK=(K-1)*L100+LT
      DO 15 N=1,N25
      LN=LK+N
      IN=IN+1
      XAT=IAT(LN)
      IF (K.NE.K4) GO TO 15
      XAT=XAT-273.16
      YAT=XAT
      RHT=RH*0.01
      IF (L.EQ.1) RHT=IAT(LN+L100)*0.01
      EXN=7.5*XAT/(XAT+237.3)
      EST=6.11*10.0**EXN
      RM=RHT*0.622*EST/(PRS(L)-EST)
      XAT=(XAT+273.16)*(1.0+0.61*RM)
      IF (N.NE.13) GO TO 15
   15 DAT1(IN)=XAT
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE UVCONV(U,V,DLON)
C
C THIS SUBROUTINE CCNVERTS GWC GRID U AND V COMPONENTS INTO SPHERICAL
C  GRID U AND V COMPONENTS.
C
C  U,V = INITIAL VALUES ARE GWC COMPONENTS
C      = FINAL VALUES ARE SPHERICAL COMPONENTS
C  DLON = LONGITUDE WEST OF GREEMWICH
C
      SPD=SQRT(U*U+V*V)
      ALPH= ATAN(U/(ABS(V)+0.00001))*5.72958
      IF (V) 1,2,2
    1 ALPH=36.0+ALPH
      GO TO 3
    2 ALPH=18.0-ALPH
    3 ALPH=ALPH-DLON*0.1+8.0
      DIR=ALPH+18.0
      IF (DIR.GT.36.0) DIR=DIR-36.0
      ANG=DIR*0.174533
      U=-SPD*SIN(ANG)
      V=-SPD*COS(ANG)
      RETURN
      END
```

```
      SUBROUTINE INTPT(I,IR,A,DX,DY,A5)
C
C THIS SUBROUTINE INTERPOLATES A VALUE BETWEEN FOUR GRID POINTS.
C
C   I = UPPER LEFT GRID POINT OF THE FOUR
C   IR = NUMBER OF POINTS IN A ROW
C   A = ARRAY CONTAINING THE GRID POINT VALUES
C   DX,DY = FRACTIONAL DISTANCE BETWEEN GRID POINTS AT WHICH INTERPOLATED
C           VALUE IS TO BE OBTAINED
C   A5 = INTERPOLATED VALUE
C
      DIMENSION A(1)
      X1=A(I)
      X2=A(I+1)
      X3=A(I+IR)
      X4=A(I+IR+1)
      A1=X1
      A3=X2
      A7=X3
      A9=X4
      A2=(X2-X1)*DX+X1
      A4=(X3-X1)*DY+X1
      A6=(X4-X2)*DY+X2
      A8=(X4-X3)*DX+X3
      A5=(DX*(A6-A4)+A4+DY*(A8-A2)+A2)*0.5
      RETURN
      END
```

```
      SUBROUTINE TREND(MVARS,NSIZE,DX,DY,DATA1,DATA2,IG) *
C   CALCULATE THE DISPLACEMENT NECESSIARY TO GIVE THE SMALLEST ROOT MEAN
C     SQUARE DIFFERENCE BETWEEN CORRESPONDING DATA VALUES OF DATA1 AND DATA2
C
C  FORMAL PARAMETERS . . . . . . . . . . . . .
C     MVARS   NUMBER OF VARIABLES (MAXIMUM IS 10)
C     NSIZE   GRID SIZE -- ASSUMED TO BE THE SAME FOR X AND Y DIRECTIONS
C     DX,DY   ON INPUT, THE INITIAL GUESS FOR THE TREND IN THE AREA, ON
C             OUTPUT, THE COMPUTED TREND (TREND IS GRID DISPLACEMENT
C             FOR BOTH CASES).
C     DATA1 AND DATA2 ARE THE ARRAYS OF DATA AT TIME 1 AND TIME 2 (OR
C             LOCATIONS 1 AND 2), RESPECTIVELY.  BOTH ARE ARRAYS, NSIZE
C             BY NSIZE (GRID SIZE) WITH NVARS VARIABLES.
C             THESE DATA ARRAYS ARE ASSUMED TO BE THREE DIMENSIONAL,
C             PACKED BY (X,Y,VARIABLE).
C
C  LOCAL PARAMETERS . . . . . . . . . . . . . . . . .
C     NTEMP    TEMPLATE SIZE (IN GRID UNITS), BOTH X AND Y DIRECTIONS
C     PTSMIN   MINIMUM NUMBER OF POINTS FOR MAKING A CALCULATION
C     DXYMAX   INITIAL GUESS MOTION -- (DX,DY) ON INPUT -- MUST BE LESS THAN THIS
C     MAXVAR   MAXIMUM NUMBER OF VARIABLES
C-----------------------------------------------------------------------------
      LOGICAL DEBUG
      DIMENSION DATA1(NSIZE,NSIZE,MVARS),DATA2(NSIZE,NSIZE,MVARS)
      DIMENSION RMSARY(5,5),AVE1(10),SDV1(10),AVE2(10),SDV2(10)
      DIMENSION ILOC(9),JLOC(9)
C
C  INITIALIZE PROGRAM CONSTANTS
      DATA  DEBUG/.FALSE./, LP/6/, MAXVAR/10/, DXYMAX/5.0/, PTSMIN/10.1/
C    ARRAYS FOR PICKING THE NEXT LOCATION TO MAKE A CALCULATION
      DATA  ILOC/0,-1,0,1,0,-1,1,1,-1/, JLOC/0,0,1,0,-1,1,1,-1,-1/
C-----------------------------------------------------------------------------
C  INTERPOLATE THE LOCATION OF THE MINIMUM RMS DIFFERENCE, GIVEN THE
C     APPARENT MINIMUM AND THE VALUE ON EACH SIDE OF THE MINIMUM
C    (FINDS THE LOCATION OF THE MINIMUM OF A PARABOLA THRU THESE 3 POINTS)
      DMIN(R1,R2,R3)  =  0.5*(R3 - R1) / (R2*2.0-R1-R3)
C  THE MINIMUM RMS DIFFERENCE AT THIS LOCATION IS GIVEN BY THIS EQUATION
      RMIN(R1,R2,R3)  =  R2 + (R3-R1)**2/(8.0*(R2*2.0-R3-R1))
C-----------------------------------------------------------------------------
C    INITIALIZE SUBROUTINE PARAMETERS
          NTEMP  =  MINO(NSIZE,10)
          NVARS  =  MINO(MVARS,MAXVAR)
          IF (DEBUG)  PRINT 1001,      NSIZE,NVARS,DX,DY
C
C    MAKE SURE INITIAL ESTIMATE OF MOTION IS WITHIN BOUNDS
          IF (ABS(DX).LT.DXYMAX .AND. ABS(DY).LT.DXYMAX)  GO TO 110
            XR  =  DX
            YR  =  DY
            DY  =  AMAX1(-DXYMAX, AMIN1(DY, DXYMAX))
            DX  =  AMAX1(-DXYMAX, AMIN1(DX, DXYMAX))
            PRINT 1000,      XR,YR,DX,DY
  110     CONTINUE
C    CALCULATE MEAN AND STANDARD DEVIATION OF EACH VARIABLE
C    THESE ARE USED LATER IN THE PROGRAM TO SCALE THE DATA FOR EACH
C    VARIABLE SO DIFFERENCES OF ALL VARIABLES CONTRIBUTE EQUALLY TO THE
```

*This subroutine was written by Dan Wolf (SRI)

```
C     ROOT MEAN SQUARE DIFFERENCE.
          DO 140  LV=1,NVARS
            AVE1(LV)  =  0.0
            AVE2(LV)  =  0.0
            SDV2(LV)  =  0.0
            SDV1(LV)  =  0.0
            DO 130  I=1,NSIZE
            DO 130  J=1,NSIZE
              AVE1(LV)  =  AVE1(LV) + DATA1(I,J,LV)
              AVE2(LV)  =  AVE2(LV) + DATA2(I,J,LV)
              SDV1(LV)  =  SDV1(LV) + DATA1(I,J,LV)**2
              SDV2(LV)  =  SDV2(LV) + DATA2(I,J,LV)**2
  130       CONTINUE
  140     CONTINUE
          PTS  =  FLOAT(NSIZE*NSIZE)
          DO 150  LV=1,NVARS
            AVE1(LV)  =  AVE1(LV)/PTS
            AVE2(LV)  =  AVE2(LV)/PTS
            SDV1(LV)  =  SQRT((SDV1(LV) - PTS*AVE1(LV)**2) / (PTS-1.0))
            SDV2(LV)  =  SQRT((SDV2(LV) - PTS*AVE2(LV)**2) / (PTS-1.0))
            IF (SDV1(LV) .LT. 0.01)  SDV1(LV) = 1.0
            IF (SDV2(LV) .LT. 0.01)  SDV2(LV) = 1.0
  150     CONTINUE
          IF (DEBUG)  PRINT 152,     (LV,AVE1(LV),SDV1(LV)
     +                                ,AVE2(LV),SDV2(LV),LV=1,NVARS)
  152     FORMAT (44H0VAR      AVE1      SDV1      AVE2      SDV2
     +            ,/,(1X,I3,4F10.2))
C     INITIALIZE ARRAY OF RMS DIFFERENCES
          DO 170  I=1,5
          DO 170  J=1,5
            RMSARY(I,J)  =  -1.0
  170     CONTINUE
C     INITIAL SECTION OF *DATA1* FROM CENTER OF THE AREA
          LI1   =  (NSIZE-NTEMP)/2 + 1
          LJ1   =  (NSIZE-NTEMP)/2 + 1
C     DISPLACE THE SECTION FROM *DATA2* BY THE INITIAL GUESS OF THE
C         MOTION FOR THE AREA (DX,DY)
C     THIS IS THE LOCATION OF THE INITIAL MINIMUM
          IMIN  =  MAX0(LI1+IFIX(DX), 1)
          JMIN  =  MAX0(LJ1+IFIX(DY), 1)
C     INITIALIZE THESE PARAMETERS EACH TIME THIS SUBROUTINE IS CALLED
          NLOC  =  0
          BEST  =  99999.9
          LMIN  =  9
C-----------------------------------------------------------------------
C     LOOP TO TRY AT LEAST 3 SUCCESSIVE LOCATIONS IN BOTH X AND Y DIRS.
  200     NLOC  =  NLOC + 1
          IF (NLOC .GT.  9  )  NLOC = 2
          IF (NLOC .EQ. LMIN)  GO TO 300
  210     LI2   =  IMIN + ILOC(NLOC)
          LJ2   =  JMIN + JLOC(NLOC)
C
          IF (DEBUG)  PRINT 221,     NLOC,LI1,LJ1, LI2,LJ2,NSIZE,NTEMP
  221     FORMAT ( 9H0LOCATION,I2,9H IN DATA1,2I5,5X,8HIN DATA2,2I5,5X
     +           ,9HGRID SIZE,I5,5X,13HTEMPLATE SIZE,I5)
C     SEE IF CALCULATION HAS BEEN MADE AT THIS LOCATION
```

```
      I1     =  LI2 - IMIN + 3
      J1     =  LJ2 - JMIN + 3
      IF (RMSARY(I1,J1) .GT. 0.0)  GO TO 200
C
C     COMPUTE THE CORRELATION BETWEEN THE NTEMP BY NTEMP DATA POINTS,
C     (TOP LEFT CORNER) AT (LI1,LJ1) OF DATA1 AND (LI2,LJ2) OF DATA2.
C         GET BEGINNING AND ENDING LOCATIONS IN X AND Y DIRECTIONS
      IE     =  MIN0(NTEMP, NSIZE+1-LI1, NSIZE+1-LI2)
      IB     =  MAX0(  1   ,    2   -LI1,     2   -LI2)
      JB     =  MAX0(  1   ,    2   -LJ1,     2   -LJ2)
      JE     =  MIN0(NTEMP, NSIZE+1-LJ1, NSIZE+1-LJ2)
      PTS    =  FLOAT((JE-JB+1)*(IE-IB+1)*NVARS)
      IF (PTS .LT. PTSMIN)   GO TO 200
C     FORM SUM OF SQUARED DIFFERENCES
      RMS    =  0.0
      DO 250  LV=1,NVARS
        SDV   =  0.5 * (SDV1(LV)+SDV2(LV))
        DO 240   I=IB,IE
          I1   =   I + LI1 - 1
          I2   =   I + LI2 - 1
          DO 230   J=JB,JE
            J1    =   J + LJ1 - 1
            J2    =   J + LJ2 - 1
            RMS   =   RMS + ((DATA1(I1,J1,LV)-DATA2(I2,J2,LV))/SDV)**2
  230     CONTINUE
  240   CONTINUE
  250 CONTINUE
C
C     CALCULATE ROOT MEAN SQUARE DIFFERENCE
      RMS    =  SQRT(RMS / PTS)
      I1     =  LI2 - IMIN + 3
      J1     =  LJ2 - JMIN + 3
      RMSARY(I1,J1)  =  RMS
      IF (RMS .GT. BEST)   GO TO 290
C
C     NEW MINIMUM RMS VALUE HAS BEEN FOUND -- MOVE POINTERS TO NEW LOCATION
      IF (NLOC .EQ. 1)   GO TO 280
C     SHIFT *RMSARY* VALUES SO THE MINIMUM VALUE IS AT (3,3)
      IDIF   =  ILOC(NLOC)
      IINC   =  1 + IDIF*( 1 -    IDIF)
      IB     =  1 + IDIF*(-2 + 2*IDIF)
      IE     =  5 + IDIF*( 1 - 2*IDIF)
      JDIF   =  JLOC(NLOC)
      JINC   =  1 + JDIF*( 1 -    JDIF)
      JB     =  1 + JDIF*(-2 + 2*JDIF)
      JE     =  5 + JDIF*( 1 - 2*JDIF)
      I      =  IB - IINC
      J      =  JB - JINC
C
  260   J     =  J + JINC
        J1    =  J + JDIF
  262     I   =  I + IINC
          I1  =  I + IDIF
          RMSARY(I,J)  =  RMSARY(I1,J1)
          IF (I .NE. IE)  GO TO 262
        I     =  IB - IINC
```

```
      IF (J .NE. JE)  GO TO 260
C
      IF (JDIF .EQ. 0)  GO TO 264
        J   =  JE + JINC
        DO 263  I=1,5
          RMSARY(I,J)  =  -1.0
  263   CONTINUE
  264 IF (IDIF .EQ. 0)  GO TO 266
        I   =  IE + IINC
        DO 265  J=1,5
          RMSARY(I,J)  =  -1.0
  265   CONTINUE
  266 CONTINUE
C     SAVE THE MINIMUM VALUE AND ITS LOCATION (IN DATA2)
      LMIN  =  NLOC
  280 BEST  =  RMS
      IMIN  =  LI2
      JMIN  =  LJ2
      IF (DEBUG)  PRINT 281,       ((RMSARY(I,J),I=1,5),J=1,5)
  281 FORMAT (10X,5F10.3)
C
C    READY TO PROCEED TO THE NEXT LOCATION
  290 CONTINUE
      IF (DEBUG)  PRINT 291,        NLOC,LMIN,IMIN,JMIN
     +                             ,IB,IE,JB,JE,PTS, RMS
  291 FORMAT (10X,8I5,F6.0,F15.6)
      IF (LMIN - NLOC)  200,210,200
C-----------------------------------------------------------------------
C    MAKE SURE THAT A CALCULATION HAS BEEN MADE AT LOCATION 9 OF SEARCH
  300 IF (NLOC .EQ. 9)  LMIN = 2
      IF (NLOC .EQ. 9)  GO TO 210
C    INTERPOLATE BETWEEN THE 3 VALUES IN BOTH DIRECTIONS TO GET
C    LOCATION OF MINIMUM RMS DIFFERENCE
      DX  =  0.0
      DY  =  0.0
      IF (RMSARY(2,3).LT.0.0 .OR. RMSARY(4,3).LT.0.0)  GO TO 310
        DX  =  DMIN(RMSARY(2,3),RMSARY(3,3),RMSARY(4,3))
        XR  =  RMIN(RMSARY(2,3),RMSARY(3,3),RMSARY(4,3))
  310 IF (RMSARY(3,2).LT.0.0 .OR. RMSARY(3,4).LT.0.0)  GO TO 320
        DY  =  DMIN(RMSARY(3,2),RMSARY(3,3),RMSARY(3,4))
        YR  =  RMIN(RMSARY(3,2),RMSARY(3,3),RMSARY(3,4))
  320 DX  =  DX + FLOAT(IMIN-LI1)
      DY  =-(DY + FLOAT(JMIN-LJ1))
C
C    PRINT IF DEBUGGING FLAG IS SET
      IF (.NOT.DEBUG)  RETURN
      PRINT 1002,     (I,I=1,5),(J,(RMSARY(I,J),I=1,5),J=1,5)
      PRINT 1003,     DX,DY,XR,YR
      RETURN
C-----------------------------------------------------------------------
 1000 FORMAT (19H0INITIAL ESTIMATE (,F5.2,1H,,F5.2
     +       ,29H) OF (DX,DY) IS TOO LARGE.  (,F5.2,1H,,F5.2
     +       ,11H) WAS USED.  )
 1001 FORMAT (17H0SUBROUTINE TREND,2I5,2F10.3)
 1002 FORMAT (22H0TREND RMS DIFFERENCES,/,5X,5I10,/,(1X,I4,5F10.5))
 1003 FORMAT(9X,12HDISPLACEMENT,2F8.3,9X,13HMIN RMS DIFFS,2F10.6)
      END
```

```
      SUBROUTINE  RAWIN(JT,I,ES,UR,VR,HR,TR,IMD,IDATE,IDIF,IGMT)
C
C THIS SUBROUTINE READS IN THE U S ARMY RAWINSONDE DATA.
C
      DIMENSION  UR(1),VR(1),HR(1),TR(1),ES(1),IMD(1)
      DIMENSION  DAT(512),IS(25),HOZ(17),PRS(6),STD(6)
      DATA ACR,CKM,CC,XNIL/0.0174533,0.5148,29.29,-999.9/
      DATA J10,J17,J24,J28,J51,K4/10,17,24,28,51,4/
      DATA  STD/    0.0,1457.0,3012.0,5574.0,0.0,0.0/
      DATA  PRS/ 870.0,850.0,700.0,500.0,300.0,200.0/
      DATA  HOZ/0.0,100.0,350.0,750.0,1250.0,1750.0,2250.0,2750.0,3250.0
     2      ,3750.0,4250.0,4750.0,5500.0,6500.0,7500.0,8500.0,9500.0/
      IMIN=1440
      ESST=1300.0
      DO 18 J=1,JT
   18 IS(J)=0
      JK= JT*K4
      DO 19 J=1,JK
      HR(J)=XNIL
      TR(J)=XNIL
      UR(J)=XNIL
   19 VR(J)=XNIL
      IF (I.GT.1) GO TO 22
C
C READS IN DATA SET
C
   20 READ 2,DAT
    2 FORMAT(10F8.1)
C
C LOOP THROUGH DATA SET IN RECORD
C
      DO 30 J=1,J10
   22 JC=(J-1)*J51+1
C
C CHECKS DATA FOR DATE,TIME,AND TYPE
C
      IP1=INT(DAT(JC)*1.0E-4)
      DATJ=DAT(JC)-IP1*1.0E4
      IP2=INT(DATJ*1.0E-2)
      IP3 =DATJ-IP2*1.0E2
      IP4=INT(DAT(JC+1)*0.01)
      IP5=DAT(JC+1)-IP4*100
      JDATE=IP5+60*(IP4+24*(IP3+IMD(IP2)+365*IP1-366))-IGMT
      IF (JDATE.LT.IDATE-IMIN) GO TO 32
      IF (JDATE.LT.IDATE-IDIF) GO TO 30
      IF (JDATE.GT.IDATE+IDIF) GO TO 32
      JS=INT(DAT(JC+2)*0.1)
      IT   =DAT(JC+2)-JS*10
      IF (IT.LT.4.OR.IT.GT.6) GO TO 30
      IF (IS(JS).EQ.6) GO TO 30
      NDATE=INT(DAT(JC))
      NTIME=INT(DAT(JC+1))
      IS(JS)=IT
      ESJS=ES(JS)
C
```

```
C SELECTS OUT HEIGHTS AND TEMPERATURES FOR THE MANDATORY LEVELS
C
      K=1
      DO 26 JQ=4,J24,4
      JK=(K-1)*JT +JS
      JCQ=JC+JQ
      IF (K.EQ.1) GO TO 25
      IF (K.GT.K4) GO TO 27
      IF (DAT(JCQ).NE.PRS(K)) GO TO 26
   25 IF (DAT(JCQ-1).LT.0.0) GO TO 125
      HR(JK)=DAT(JCQ-1)-STD(K)
      TR(JK)=DAT(JCQ+1)+273.16
      IF (K.NE.1) GO TO 125
      PRS1=((ESJS-ESST)/(TR(JK)*CC)+1.0)*DAT(JCQ)
                     HR(JK)=-(DAT(JCQ)- PRS1 )*TR(JK)*CC/DAT(JCQ)
  125 K=K+1
   26 CONTINUE
   27 KT=K-1
C
C INTERPOLATES ZONAL WIND VALUES TO OBTAIN VALUES FOR MANDATORY LEVELS
C
      JCJ=JC+J28-1
      IF (ABS(DAT(JCJ)).GT.360.0) GO TO 127
      ANG=ACR*DAT(JCJ)
      UR(JS)=-DAT(JCJ+1)*SIN(ANG)*CKM
      VR(JS)=-DAT(JCJ+1)*COS(ANG)*CKM
  127 J2=2
      DO 29 K=2,KT
      JK=(K-1)*JT +JS
      JG=JCJ
      DO 28 JH=J2,J17
      JG=JG+2
      JI=JG+1
      HRJK=HR(JK)+STD(K)
      IF (HOZ(JH)+ESJS.LT.HRJK)    GO TO 28
      RH=  (HRJK-HOZ(JH-1)-ESJS)/(HOZ(JH)-HOZ(JH-1))
      IF (ABS(DAT( JG)).GT.360.0) GO TO 128
      UR(JK)=(-RH*DAT(JI)*SIN(ACR*DAT(JG))+DAT(JI-2)*SIN(ACR*DAT(JG-2))*
     2(RH-1.0))*CKM
      VR(JK)=(-RH*DAT(JI)*COS(ACR*DAT(JG))+DAT(JI-2)*COS(ACR*DAT(JG-2))*
     2(RH-1.0))*CKM
  128 J2=JH
      GO TO 29
   28 CONTINUE
   29 CONTINUE
   30 CONTINUE
      GO TO 20
   32 CONTINUE
      JSM=0
      DO 150 J=1,JT
      IF (IS(J).GT.0) JSM=JSM+1
  150 CONTINUE
      PRINT 1,JSM
    1 FORMAT(10X,37HU S ARMY RAWINSONDE DATA READ IN FOR ,I2,9H-STATIONS
     2        ,//)
      RETURN
      END
```

```
      SUBROUTINE MESH(KQ,JJ,YS,XS,VS,US,HS,TS,YL,XL,VL,UL,HL,TL)
C
C THIS SUBROUTINE COMPUTES GRID POINT VALUES FROM OBSERVED DATA AND AN INITIAL
C  GUESS GRID POINT FIELD  (IF KQ = 2) BY A LEAST SQUARES FITTING OF THE DATA
C  (SEE ENDLICH AND MANCUSO, MON WEA REV, 1968, 342-350). IT CAN ALSO BE USED TO
C  GENERATE ITS OWN INITIAL GUESS FIELD (IF KQ = 1). ALTHOUGH THIS PARTICULAR
C  SUBROUTINE HAS BEEN SET UP FOR ANALYZING WIND COMPONENTS, IT CAN ALSO
C  BE USED TO ANALYZE ANY 3 QUANTITIES THAT ARE PLACED IN ARRAYS HS,US,
C  AND VS (IDS SHOULD BE SET TO ZERO IN ORDER TO BYPASS THE UPSTREAM,
C  TIME, AND HEIGHT WEIGHTING EFFECTS)
C
C THIS SUBROUTINE ALSO INCLUDES THE ENTRY POINT TO SUBROUTINE MESHSET.
C
C  JJ = NUMBER OF WIND DATA
C  KS = NUMBER OF CLOSEST DATA TO A GRID POINT USED TO COMPUTE ITS VALUE
C  W1 = WEIGHT GIVEN TO INITIAL GUESS VALUE AT GRID POINT
C  C2 = WEIGHTING CONSTANT
C  APH1,APH2,APH3 = WEIGHTING FACTORS FOR UPSTREAM, TIME, AND HEIGHT EFFECTS
C  RMAX = MAXIMUN RADIUS OVER WHICH THE KS CLOSEST DATA ARE SELECTED FOR
C          COMPUTING A GRID POINT VALUE (DEG LATITUDE)
C  X15 = LONGITUDINAL RANGE (+X15 TO -X15) OVER WHICH THE SEARCH FOR THE
C         KS CLOSEST DATA IS MADE (DEG LONGITUDE)
C  YS,XS = LATITUDE AND LONGITUDE OF WIND DATA (DEG)
C  US,VS = U AND V COMPONENTS OF WIND DATA (M SEC-1)
C  UN,VN(KQ=1) = INITIAL VALUES -- NOT USED
C              = FINAL VALUES --- A SMOOTH ANALYSIS USED AS THE INITIAL GUESS
C                                  FIELD IN THE KQ=2 COMPUTATION
C  UN,VN(KQ=2) = INITIAL VALUES --- USED AS THE INITIAL GUESS FIELD
C              = FINAL VALUES --- USED AS THE FINAL ANALYSIS
C  HS,HN = INITIAL DATA AND ANALYZED GRID POINT VALUES FOR AN ARBITRARY QUANTITY
C
      DIMENSION  DS( 50),JS( 50),IQ( 50),DVR(20)
      DIMENSION YS(1),XS(1),VS(1),US(1),HS(1),TS(1)
      DIMENSION YL(1),XL(1),VL(1),UL(1),HL(1),TL(1)
      COMMON/CIS/ IS(1000)
      COMMON/CGD/ M9,N9,I9,M8,N8,Y8,X8,DD
      COMMON/CPTS/   KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      EQUIVALENCE (DVR(1),DNH),(DVR(2),DHH),(DVR(3),DUH),(DVR(4),DVH),
     2  (DVR(5),DTH),(DVR(6),DXH),(DVR(7),DYH),(DVR(8),DXYH),
     3  (DVR(9),DXXH),(DVR(10),DYYH),(DVR(11),DXHH),(DVR(12),DXUH),
     4  (DVR(13),DXVH),(DVR(14),DYHH),(DVR(15),DYUH),(DVR(16),DYVH),
     5  (DVR(17),DXTH),(DVR(18),DYTH)
      IF (KQ.LT.1) GO TO 18
      KQ5=KQ-1+KSS5
      M=0
      L=0
      I=0
   75 M=M+1
      IF (M-M9) 77,77,100
   77 N=0
      YLM=YL(M)
      CM=COS(ACR*YLM)
   80 N=N+1
      IF (N-N9) 81,81,75
   81 L=L+1
```

```
      K=0
      NOD=0
      XLN=XL(N)
      IF (KQ-1) 83,82,83
   82 NOD=0
      DO 182 IK=1,5
  182 DVR(IK)=0.0
      GO TO 84
   83 DO 183 IK=6,18
  183 DVR(IK)=0.0
      W=W1
      DNH=W
      NOD=1
      K=0
      DHH=HL(L)*W
      DUH=UL(L)*W
      DVH=VL(L)*W
      DTH=TL(L)*W
   84 K=K+1
      IF (K-KS) 85,85,90
  384 I=I+KS-K
      GO TO 90
   85 I=I+1
      IF (NOD-KQ5)  86,384,384
   86 J=IS(I)
      IF (J)   84, 84,87
   87 IF (ABS(US(J)).GT.100.0) GO TO 84
      XSJ=XS(J)
      YSJ=YS(J)
      USJ=US(J)
      VSJ=VS(J)
      HSJ=HS(J)
      TSJ=TS(J)
      DYS=YSJ-YLM
      DXS= (XLN-XSJ)*CM
      DYS2=DYS*DYS+DXS*DXS
      DXS2=0.5*DYS2
      IF (IDS.EQ.0)  GO TO 385
      USK=USJ
      VSK=VSJ
      IF (KQ.EQ.1) GO TO 388
      USK=USJ+UL(L)
      VSK=VSJ+VL(L)
  388 DXS1=USK*USK+VSK*VSK+0.01
      DXS2=(USK*DYS-VSK*DXS)
      DXS2=DXS2*DXS2/DXS1
  385 W= C2/(DYS2+DXS2*ALPH+ C2)
      NOD=NOD+1
      DNH=DNH+W
      TSJ=TSJ*W
      HSJ=HSJ*W
      USJ=USJ*W
      VSJ=VSJ*W
      DHH=DHH+HSJ
      DUH=DUH+USJ
      DVH=DVH+VSJ
```

```
      DTH=DTH+TSJ
      IF (KQ-1) 89,84,89
   89 DYH=DYH+DYS*W
      DXH=DXH+DXS*W
      DXYH=DXYH+DXS*DYS*W
      DXXH=DXXH+DXS*DXS*W
      DYYH=DYYH+DYS*DYS*W
      DXHH=DXHH+HSJ*DXS
      DYHH=DYHH+HSJ*DYS
      DXTH=DXTH+TSJ*DXS
      DYTH=DYTH+TSJ*DYS
      DXUH=DXUH+USJ*DXS
      DYUH=DYUH+USJ*DYS
      DXVH=DXVH+VSJ*DXS
      DYVH=DYVH+VSJ*DYS
      GO TO 84
   90 CONTINUE
      IF (KQ-1) 94,91,94
   91 IF (NOD-2) 80,92,92
   92 IF (DNH) 80,80,93
   93 DNH=1.0/DNH
      HL(L)=DHH*DNH
      UL(L)=DUH*DNH
      VL(L)=DVH*DNH
      TL(L)=DTH*DNH
      GO TO 80
   94 IF (NOD-3) 80,80,95
   95 D=DYH*DYH-DNH*DYYH
      E=DXYH*DYH-DXH*DYYH
      A=DXH*DYH-DNH*DXYH
      B=DXXH*DYH-DXH*DXYH
      BDAE=B*D-A*E
      IF (BDAE) 97,80,97
   97 BI=1.0/BDAE
      C =DXHH*DYH-DHH*DXYH
      F =DYHH*DYH-DHH*DYYH
      CT=DXTH*DYH-DTH*DXYH
      FT=DYTH*DYH-DTH*DYYH
      CU=DXUH*DYH-DUH*DXYH
      FU=DYUH*DYH-DUH*DYYH
      CV=DXVH*DYH-DVH*DXYH
      FV=DYVH*DYH-DVH*DYYH
      HL(L)=(B*F-C*E)*BI
      UL(L)=(B*FU-CU*E)*BI
      VL(L)=(B*FV-CV*E)*BI
      TL(L)=(B*FT-CT*E)*BI
      GO TO 80
  100 CONTINUE
      RETURN
C
C THIS SUBSECTION DETERMINES A SET OF KS CLOSEST OBSERVATIONS FOR
C  EACH GRID POINT.   THE OBSERVATIONS INDENTIFYING INDICIES ARE STORED
C  IN ARRAY IS (IS DIMENSIONS MUST BE GREATER OR LESS THAN LR*LC*KS)
C
   18 ACR=3.1416/180.0
      DLCK=RMAX*RMAX
```

```
      JCT= 50
      JS(JCT)=-1
      DS(JCT)=DLCK
      JC2=JCT-2
      M=0
      L=0
      I=0
   20 M=M+1
      N=0
      YLM=YL(M)
      CM=COS(ACR*YLM)
   25 N=N+1
      L=L+1
      J=0
      JT=JJ
      XLN=XL(N)
      XLCK=DLCK
   29 J=0
      JC=0
   30 J=J+1
      DYS=YS(J)-YLM
      DXS=(XLN-XS(J))*CM
      DLS=DYS*DYS+DXS*DXS
      IF (DLS-XLCK)  32,33,33
   32 JC=JC+1
      IF (JC.LT.JCT)  GO TO 31
      XLCK=XLCK-10.0
      GO TO 29
   31 DS(JC)=DLS
      JS(JC)=J
      IYS=0
      IXS=1
      IF (DXS.LT.0) IXS=2
      IF (DYS.LT.0) IYS=2
      IQ(JC)=IYS+IXS
   33 IF (J-JT) 30,34,34
   34 KP=0
      K=0
      JQ=1
      ISW=1
      JX=JC
      IF (KSW.LT.1)  ISW=2
   35 K=K+1
      SIL=DLCK
      J=0
      I=I+1
      KP=KP+1
      JC=JCT
   40 J=J+1
      IF (J.LE.JX) GO TO (41,42),ISW
      GO TO 45
   41 IF (IQ(J).NE.JQ) GO TO 40
   42 IF (DS(J)-SIL)  44,40,40
   44 SIL=DS(J)
      JC=J
      GO TO 40
```

```
45 DS(JC)=DLCK
   IS(I)=JS(JC)
   JQ=JQ+1
   IF (JQ.GT.4) JQ=1
   IF (KP.EQ.KSW) ISW=2
   IF (JC.LT.JCT) GO TO 49
   IF (KP.GT.KSW)  GO TO 49
   K=K-1
   I=I-1
   GO TO 35
49 IF (K-KS) 35,50,50
50 IF (N-N9) 25,55,55
55 IF (M-M9) 20,60,60
60 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE CHECK  (JJ,YS,XS,VS,US,YL,XL,VN,UN)
C
C THISSUBROUTINE CHECKS THE OBSERVED WIND VALUES BY COMPARING THEM
C  TO ANALYZED WIND VALUES  (THE U AND V OF THE INCONSISTENT DATA ARE
C  SETAT 999.9 ).
C
C  JJ = NUMBER OF WIND DATA
C  YS,XS = LATITUDE AND LONGITUDE OF WIND DATA (DEG)
C  US,VS = U AND V COMPONENTS OF WIND DATA
C  YL,XL = LATITUDE AND LONGITUDE OF ROWS AND COLUMNS
C  UN,VN = GRID POINT U AND V WIND COMPONENTS
C  CRT= CRITICAL VALUE USED IN TESTING WIND DATA
C  WIM= WEIGHT GIVEN TO A WIND IN ANALYZING A VALUE AT ITS LOCATION
C       AND WEIGHT GIVEN TO NEAREST GRID POINT VALUE (NOW CALLED SIM AND
C       GIM)
C
      LOGICAL DEBUG
      DIMENSION JST( 26),DST( 26),WTS( 25),DVR(20)
      DIMENSION XS( 1),YS( 1),VS( 1),US( 1)
      DIMENSION XL( 1),YL( 1),UN( 1),VN( 1)
      COMMON/CIS/ IS(1000)
      COMMON/CCHK/ CRT,SIM,GIM,IWND
      COMMON/CPTS/   KS,W1,C2,RMAX,KSS5,IDS,KSW,ALPH
      COMMON/CGD/ M9,N9,I9,M8,N8,Y8,XB,DD
      EQUIVALENCE (USK,USJ),(VSK,VSJ)
      EQUIVALENCE (DVR(1),DNH),(DVR(2),DHH),(DVR(3),DUH),(DVR(4),DVH),
     2  (DVR(5),DTH),(DVR(6),DXH),(DVR(7),DYH),(DVR(8),DXYH),
     3  (DVR(9),DXXH),(DVR(10),DYYH),(DVR(11),DXHH),(DVR(12),DXUH),
     4  (DVR(13),DXVH),(DVR(14),DYHH),(DVR(15),DYUH),(DVR(16),DYVH),
     5  (DVR(17),DXTH),(DVR(18),DYTH)
      DATA  DEBUG/.FALSE./

    4 FORMAT(21X,,13H DELETED DATA/)
    5 FORMAT (49H     LAT(DEG)  LON(DEG)  U(KTS)    V(KTS)    TEST,/)
    6 FORMAT(1X,10F10.2)
      PRINT 4
      PRINT 5
C
C BASIC COMPUTATIONS
C
      JT=JJ
      ACR=3.1416/180.0
      YDI=1.0/DD
      XDI=1.0/DD
      KQ5=KSS5+2
      IF (IWND.GT.0) KQ5=KQ5+1
      SPH1=ALPH*ALPH
      CR5=1.25*CRT
C
C ANALYSIS OF WINDS  AT MEASUREMENT LOCATIONS (SIMILAR TO METHOD USED
C  IN SUBROUTINE MESH).
C
      KG=0
   20 JX=0
      LX=0
```

```
      CRW=CRS
      IF (KG.EQ.2) CRW=CRT
   80 LX=LX+1
      IF (LX-JT)  82,82,100
   82 L=LX
      IF (KG.NE.0) L= JST(LX)
      IF (ABS(US(L)).GT.100.0) GO TO 80
      YLM=YS(L)
      XLN=XS(L)
      M=(YL(1)-YLM)*YDI+1.5
      N=(XLN-XL(1))*XDI+1.5
      IF (M.LT.1) M=1
      IF (M.GT.M9)  M=M9
      IF (N.LT.1) N=1
      IF (N.GT.N9)  N=N9
      LI=N9*(M-1)+N
      I=(LI-1)*KS
      CM=COS(ACR*YLM)
      NOD=0
      K=0
      DO 182 IK=1,18
  182 DVR(IK)=0.0
      IF (IWND.LE.0) GO TO 84
      XSJ=XL(N)
      YSJ=YL(M)
      USJ=UN(LI)
      VSJ=VN(LI)
      DYS=YSJ-YLM
      DXS=(XSJ-XLN)*CM
      W=GIM
      GO TO 89
   84 K=K+1
      IF (K-KS) 85,85,90
   85 I=I+1
      IF (NOD-KQ5)   86,84,84
   86 J=IS(I)
      IF (J)      84,84,87
   87 IF (ABS(US(J)).GT.100.0) GO TO 84
      USJ=US(J)
      VSJ=VS(J)
      XSJ=XS(J)
      YSJ=YS(J)
      DYS=YSJ-YLM
      DXS=(XSJ-XLN)*CM
      W=SIM
      IF (J.EQ.L) GO TO 389
      DXS2=0.0
      DYS2=DYS*DYS+DXS*DXS
      IF (IDS.LT.1) GO TO  88
      DXS1=USK*USK+VSK*VSK+0.01
      DXS2=(USK*DYS-VSK*DXS)
      DXS2=DXS2*DXS2/DXS1
   88 W=C2/(DYS2+DXS2*SPH1+C2)
  389 IF (KG.NE.0)  W=W*WTS(J)
   89 NOD=NOD+1
      DNH=DNH+W
```

```
      USJ=USJ*W
      VSJ=VSJ*W
      DUH=DUH+USJ
      DVH=DVH+VSJ
      DYH=DYH+DYS*W
      DXH=DXH+DXS*W
      DXYH=DXYH+DXS*DYS*W
      DXXH=DXXH+DXS*DXS*W
      DYYH=DYYH+DYS*DYS*W
      DXUH=DXUH+USJ*DXS
      DYUH=DYUH+USJ*DYS
      DXVH=DXVH+VSJ*DXS
      DYVH=DYVH+VSJ*DYS
      GO TO 84
   90 CONTINUE
   94 IF (NOD-3) 80.80.95
   95 D=DYH*DYH-DNH*DYYH
      E=DXYH*DYH-DXH*DYYH
      A=DXH*DYH-DNH*DXYH
      B=DXXH*DYH-DXH*DXYH
      BDAE=B*D-A*E
      IF (BDAE) 97.80.97
   97 BI=1.0/BDAE
      XU=DXUH*DYH-DUH*DXYH
      YU=DYUH*DYH-DUH*DYYH
      XV=DXVH*DYH-DVH*DXYH
      YV=DYVH*DYH-DVH*DYYH
      ULL =(B*YU-XU*E)*BI
      VLL =(B*YV-XV*E)*BI
C
C CHECK FOR FOR INCONSISTENCY BETWEEN ANALYZED AND MEASURED WINDS
C
      ALTH1= ULL*ULL+VLL*VLL
      ALTH2= US(L)*US(L)+VS(L)*VS(L)
      BLTH=ALTH1
      IF(ALTH2 .GT. ALTH1) BLTH= ALTH2
      PERP1=(ULL*US(L) +VLL*VS(L))/BLTH
      IF (DEBUG)
     2PRINT 6, YS(L),XS(L),US(L),VS(L),PERP1,ULL,VLL,CRW,CR5,CRT
      DLS=PERP1
      WTS(L)=1.0
      IF (DLS.GT.CR5) GO TO 80
      WTS(L)=0.5
      IF (DLS.GT.CRW)  GO TO 80
      IF (KG.EQ.2)  GO TO 99
      WTS(L)=SIM
      IF (JX.GT.25)   GO TO 100
      JX=JX+1
      JST(JX) =L
      DST(JX) = PERP1
      GO TO 80
   99 PRINT 6, YS(L),XS(L),US(L),VS(L),PERP1
      US(L) =-999.9
      VS(L) =-999.9
      GO TO 80
  100 CONTINUE
```

```
C
C ORDER SUSPECT DATA ACCORDING TO HIGHEST PERPI VALUES AND REPEAT ABOVE
C
      IF (JX.LE.0) GO TO 300
      JT=JX
      IF (KG.EQ.0) GO TO 202
      IF (KG.NE.1) GO TO 300
      DO 200 J1=1,JT
      J3=J1
      DO 150 J2=J1,JT
      IF (DST(J2) .LT. DST(J3))  J3=J2
  150 CONTINUE
      IST=JST(J1)
      XST=DST(J1)
      JST(J1)=JST(J3)
      DST(J1)=DST(J3)
      JST(J3)=IST
      DST(J3)=XST
  200 CONTINUE
  202 KG=KG+1
      GO TO 20
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE KID(IV,ID,IB,VOR,DIV,BAL,U,V,C,T)
C
C THIS SUBROUTINE COMPUTES FIELDS OF VORTICITY,DIVERGENCE,AND THE
C BALANCE HEIGHT TERM.
C
C IV,ID,IB = COMPUTES VORTICITY,DIVERGENCE AND BALANCE TERM WHEN
C IV,ID AND IB ARE SET GT 0
C VOR,DIV,BAL = VORTICITY,DIVERGENCE AND BALANCE TERM VALUES
C U,V = U AND V WIND COMPONENTS
C C,T = LATITUDINAL COSINE AND TANGENT VALUES
C
      DIMENSION VOR(1),DIV(1),BAL(1),U(1),V(1),C(1),T(1)
      COMMON/CGD/ M9,N9,I9,M8,N8,Y8,X8,DD
      DATA ACR,G,R,TDEL /0.0174533,9.8062,6.371E6,1.4584E-4/
      ERI=1.0/R
      GI=1.0/G
      DY=DD*R*ACR
      DYI=1.0/(DY+DY)
      IVB=0
      IF (IV.GT.0.OR.IB.GT.0) IVB=1
      DO 50 M=2,M8
      CM=C(M)
      DYIS=DYI/CM
      TNGR=T(M)*ERI
      IF (IB.LT.1) GO TO 10
      CM2=0.5*GI*CM
      HC2=DY*CM*DY*CM
      BFM  =GI*TDEL*ERI*CM
      CFM  =GI*TDEL*CM*T(M)
   10 DO 40 N=2,N8
      I=(M-1)*N9+N
      IF (ID.LT.1) GO TO 20
      DUE=DYIS*(U(I+1)-U(I-1))
      DVN=DYI*(V(I-N9)-V(I+N9))
      DIV(I)=DUE+DVN-V(I)*TNGR
   20 IF (IVB.LT.1) GO TO 40
      DVE=DYIS*(V(I+1)-V(I-1))
      DUN=DYI*(U(I-N9)-U(I+N9))
      VORI = DVE-DUN+U(I)*TNGR
      IF (IV.GT.0) VOR(I)=VORI
      IF (IB.GT.0)
     1BAL(I)=   (VORI*CFM   -U(I)*BFM   )*HC2
     2          -CM2*((V(I+1)-V(I-1))*(U(I-N9)-U(I+N9))
     3          -(U(I+1)-U(I-1))*(V(I-N9)-V(I+N9)))
   40 CONTINUE
   50 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ALTERS(LGM,CTV,FAC,TNG,CS,UN,VN,VV,DV)
C
C THIS SUBROUTINE CHANGES THE INITIAL WIND FIELD INTO A NONDIVERGENT
C   FIELD THAT FITS THE SPECIFIED VORTICITY AND DIVERGENCE FIELDS.
C
C SPHERICAL GRID VERSION.
C
C     LGM = MAXIMUM NUMBER OF ITERATIONS.
C     CTV = ERROR TOLERANCE IN VORTICITY AND DIVERGENCE FIELDS (SEC-1).
C     FAC = WIND ADJUSTMENT FACTOR.
C     CS,TNG    = ARRAYS CONTAINING LATITUDINAL COSINES AND TANGENTS.
C     UN,VN = ACTUAL WIND COMPONENTS - INITIAL VALUES (M SEC-1).
C     UN,VN = NONDIVERGENT WIND COMPONENTS - FINAL VALUES (M SEC-1).
C     VV  = VORTICITY (SEC-1).
C     DV = DIVERGENCE (SEC-1)
C
      LOGICAL DEBUG
      DIMENSION TNG(1),CS(1),UN(1),VN(1),VV(1),DV(1)
      COMMON/CGD/ M9,N9,I9,M8,N8,YB,XB,DD
      EQUIVALENCE (LR,M9),(LC,N9)
      DATA  DEBUG/.FALSE./
C
C PRELIMENARY COMPUTATIONS.
C
      R=6.371E6
      DY=DD*R*3.1416/180.0
      LG=0
      DY2=DY+DY
      DYRA5=DY*FAC
      ERI=1.0/R
      DYI=1.0/DY2
      LR1=LR-1
      LC1=LC-1
      XRCI=1.0/(LR*LC)
C
C COMPUTATION OF AVERAGE U AND V VALUES.
C
      SUM1=0.0
      SUM2=0.0
      I=1
      DO 8 J=1,LR
      DO 8 K=1,LC
      SUM1= SUM1 + UN(   I)
      SUM2= SUM2 +VN(   I)
    8 I=I+1
      SUM1=SUM1*XRCI
      SUM2=SUM2*XRCI
C
C BEGINNING OF ITERATION LOOP.
C
   10 LG =LG+1
      DIFD=0.0
      DIFV=0.0
C
C BEGINNING OF GRID POINT LOOP.
```

```
C
      DO 500 J=2,LR1
      TNG637=TNG(J)*ERI
      DYISEC=DYI/CS(J)
      DYRACS=DYRA5*CS(J)
      DO 500 K=2,LC1
      I=(J-1)*LC+K
      IP1=I+1
      IM1=I-1
      IP9=I+N9
      IM9=I-N9
C
C ALTER WINDS TO FIT A ZERO DIVERGENCE.
C
      DUE=DYISEC*(UN(   IP1)-UN(   IM1))
      DVN = DYI*(VN(   IM9)-VN(   IP9))
      DIJK    =DUE+DVN-VN(   I)*TNG637
      DIF=DV(I)-DIJK
      IF (ABS(DIF).GT.DIFD) DIFD=ABS(DIF)
      CUJK    =DYRACS*DIF
      CVJK    =DYRA5*DIF
      VN(   IP9) = VN(   IP9) - CVJK
      VN(   IM9) = VN(   IM9) + CVJK
      UN(   IP1) = UN(   IP1) + CUJK
      UN(   IM1) = UN(   IM1) - CUJK
C
C ALTER WINDS TO FIT THE SPECIFIED VORTICITY VALUE.
C
      DVE=DYISEC*(VN(   IP1)-VN(   IM1))
      DUN = DYI*(UN(   IM9)-UN(   IP9))
      VOJK    =DVE-DUN+UN(   I)*TNG637
      VIF=VV(   I)-VOJK
      IF (ABS(VIF).GT.DIFV) DIFV=ABS(VIF)
      CVJK    =DYRACS*VIF
      CUJK    =DYRA5*VIF
      UN(   IP9) = UN(   IP9) + CUJK
      UN(   IM9) = UN(   IM9) - CUJK
      VN(   IP1) = VN(   IP1) + CVJK
      VN(   IM1) = VN(   IM1) - CVJK
  500 CONTINUE
C
C CHECK OF ITERATION NUMBER AND MAXIMUM DIFFERENCE BETWEEN THE SPECIFIED
C   VORTICITIES AND DIVERGENCES AND THOSE COMPUTED FROM THE WIND VALUES.
C
      IF (LG.GE.LGM)  GO TO 600
      IF (DIFD.GT.CTV.OR.DIFV.GT.CTV) GO TO 10
  600 CONTINUE
C
C ADJUSTMENT OF U AND V FIELDS TO AVERAGE VALUES OF INITIAL FIELDS.
C
      SUM3=0.0
      SUM4=0.0
      I=1
      DO 810 J=1,LR
      DO 810 K=1,LC
      SUM3= SUM3 + UN(   I)
```

```
      SUM4= SUM4 +VN(   I)
  810 I=I+1
      SUM3=SUM3*XRCI
      SUM4=SUM4*XRCI
      SUM5=SUM1-SUM3
      SUM6=SUM2-SUM4
      I=1
      DO 820  J=1,LR
      DO 820  K=1,LC
      UN(   I)= UN(   I)+SUM5
      VN(   I)= VN(   I)+SUM6
  820 I=I+1
C
C PRINTOUT OF MAXIMUM DIFFERENCES AND COMPUTER TIME.
C
           IF (DEBUG)
     2PRINT 2000,LG,DIFV,DIFD,RT2
 2000 FORMAT(2X,"NO OF ITERATIONS = ",I3,5X,"MAX VORT ERROR =",E11.2,5X,
     2"MAX DIV ERROR =",E11.2,5X,"CP TIME =",E11.2)
C
C END OF SUBROUTINE ALTERS.
C
      RETURN
      END
```

```
      SUBROUTINE   BALHGT(NR,NC,DLAT,IBT,NIT,WC,EPS,AVE,CF,TF,HL,XOR)
C
C THISSUBROUTINE SOLVES THE POISSON EQ. (LAPLACIAN OF  HL=XOR ) FOR THE
C    SCALAR FIELD ANAL USING THE ALTERNATING DIRECTION IMPLICIT (ADI)
C    METHOD OF RELAXATION (YOUNG,D.M.,SURVEY OF NUMERICAL ANALYSIS,
C    MCGRAW-HILL,1962, EDITED BY J.TODD).  A FIRST GUESS FIELD SHOULD BE
C    SUPPLIED FOR  HL, HOWEVER,AN EQUIVALENT RESULT CAN BE OBTAINED WITH
C    ADDITIONAL ITERATIONS.
C
C       NR,NC = TOTAL NUMBER OF ROWS AND COLUMNS IN GRID.
C       DLAT = UNIFORM SPHERICAL MESH SIZE IN DEGREES.
C       IBT = INDICATOR SPECIFYING TYPE OF BOUNDARY CONDITIONS.
C       (IBT.LE.0) MEANS FIXED BOUNDARY CONDITIONS.
C       (IBT.GT.0) MEANS NORMAL DERIVATIVE BOUNDARY CONDITIONS.
C       NIT = NUMBER OF ITERATIONS TO BE PERFORMED.
C       WC = RELAXATION FACTOR.
C       EPS = RELAXATION TOLERANCE -IF THE CHANGES IN  HL  DURING THE ROW
C       IMPROVEMENTS OF THE NTH ITERATION ARE LESS THEN EPS,
C       THE RELAXATION IS STOPPED AFTER THE (N+1)TH ITERATION.
C       AVE = AVERAGE VALUE SPECIFIED FOR HL  -  THE FIELD IS ADJUSTED
C       TO THIS AVERAGE VALUE IF (IBT.LE.0)
C       CF,TF = TWO ARRAYS CONTAINING LATITUDINAL SINE AND TANGENT VALUES.
C       HL   =   THE SCALAR FIELD TO BE DETERMINED (M2SEC-1 OR M).
C       XOR  =   THE FORCING FUNCTION (M2SEC-1 OR M).
C
      LOGICAL DEBUG
      DIMENSION  TY(10),BB(10),B1(10),B2(10),E(10),F(10)
      DIMENSION  HL(1),XOR(1),CF(1),TF(1)
      DIMENSION    BDW(10),BDE(10),BDN(10),BDS(10)
C
C PRELIMENARY COMPUTATIONS.
C
      DATA M1,N1,ACR/2,2,0.0174533/
      DATA  DEBUG/.FALSE./
      M9=NR-1
      N9=NC-1
      I9=NR*NC
      I9M=I9-N9
      ICS=1
      IRS=NC
      IF (IBT.LE.0) GO TO 100
      DO 62 M=M1,M9
      I=(M-1)*IRS+1
      BDW(M)=HL(I)-HL(I+ICS)
      I=I+N9*ICS
   62 BDE(M)=HL(I)-HL(I-ICS)
      DO 64 N=N1,N9
      I=(N-1)*ICS+1
      BDN(N)=HL(I)-HL(I+IRS)
      I=I+M9*IRS
   64 BDS(N)=HL(I)-HL(I-IRS)
      G=9.8062
      TDEL=1.4584E-4
      R=6.371E6
      CR=3.1416/180.0
```

```
      CON=1.0
      CIR=0.0
      VOR=0.0
      DO 70 M=M1,M9
      CSI=1.0/(CF(M)*CF(M)*TF(M))
      CIR=CIR+BDW(M)*CSI
   70 CIR=CIR+BDE(M)*CSI
      S1=2.0/(TF(M1)+TF(M1-1))
      S9=2.0/(TF(M9)+TF(M9+1))
      DO 75 N=N1,N9
      CIR=CIR+BDN(N)*S1
   75 CIR=CIR+BDS(N)*S9
      CIR=CIR*CON
      DO 80 M=M1,M9
      FCM=1.0/CF(M)
      DO 80 N=N1,N9
      I=(M-1)*NC+N
   80 VOR=VOR+XOR(I)*FCM
      DIF=(VOR-CIR)*0.5/(M9+N9-2)
      DIF=DIF/CON
      DO 85 M=M1,M9
      CSI=CF(M)*CF(M)*TF(M)
      BDW(M)=BDW(M)+DIF*CSI
   85 BDE(M)=BDE(M)+DIF*CSI
      S1=(TF(M1)+TF(M1-1))*0.5
      S9=(TF(M9)+TF(M9+1))*0.5
      DO 90 N=N1,N9
      BDN(N)=BDN(N)+DIF*S1
   90 BDS(N)=BDS(N)+DIF*S9
      CIR=0.0
      DO 91 M=M1,M9
      CSI=1.0/(CF(M)*CF(M)*TF(M))
      CIR=CIR+BDW(M)*CSI
   91 CIR=CIR+BDE(M)*CSI
      S1=2.0/(TF(M1)+TF(M1-1))
      S9=2.0/(TF(M9)+TF(M9+1))
      DO 92 N=N1,N9
      CIR=CIR+BDN(N)*S1
   92 CIR=CIR+BDS(N)*S9
      CIR=CIR*CON
  100 DH=DLAT*ACR*0.5
      DO 150 M=M1,M9
      BB(M)=CF(M)*CF(M)
  150 TY(M)=DH*CF(M)*CF(M)*TF(M)
      NI=0
      NIP=NIT
  180 WCI=1.0/WC
      WC1=1.0-WC
      DO 190 M=M1,M9
      B1(M)=(BB(M)+BB(M)+2.0)*WCI
  190 B2(M)=B1(M)*WC1
C
C BEGINNING OF ADI ITERATION LOOP.
C
  200 NI=NI+1
C
```

```
C SUCCESSIVE ROW IMPROVEMENT.
C
      RLI=0.0
      DO 215 M=M1,M9
      I=(M-1)*IRS+1
      BBM=BB(M)
      B1M=B1(M)
      B2M=B2(M)
      TYM=TY(M)
      BPT=BBM+TYM
      BMT=BBM-TYM
      IF (IBT.LT.1) GO TO 204
      E(1)=   1.0
      F(1)=   BDW(M)
      GO TO 206
  204 E(1)=   0.0
      F(1)=   HL(I)
  206 I=I+ICS
      DO 210 N=N1,N9
  208 E(N)=   1.0/(B1M-E(N-1))
      F(N)=(HL(I+IRS)*BPT+HL(I-IRS)*BMT+B2M*HL(I)-XOR(I)+F(N-1))*E(N)
  210 I=I+ICS
      NB=N9+1
      IF (IBT.GT.0)  HL(I)=(BDE(M)+F(N9))/(1.0-E(N9))
      DO 213 N=N1,N9
      I=I-ICS
      NB=NB-1
      DLI=HL(I)-E(NB)*HL(I+ICS)-F(NB)
      ALI=ABS(DLI)
      IF (ALI.GT.RLI) RLI=ALI
  213 HL(I)=HL(I)-DLI
      IF (IBT.GT.0)  HL(I-ICS)=E(NB-1)*HL(I)+F(NB-1)
  215 CONTINUE
C
C SUCCESSIVE COLUMN IMPROVEMENT.
C
      DO 240 N=N1,N9
      I=(N-1)*ICS+1
      IF (IBT.LT.1) GO TO 214
      E(1)=   1.0
      F(1)=   BDN(N)
      GO TO 216
  214 E(1)=   0.0
      F(1)=   HL(I)
  216 I=I+IRS
      DO 230 M=M1,M9
  218 TYM=TY(M)
      BMT=BB(M)-TYM
      EI=1.0/(B1(M)-BMT*E(M-1))
      E(M)=   (BB(M)+TYM)*EI
      F(M)=FT
      FT =    (HL(I+ICS)+HL(I-ICS)+B2(M)*HL(I)-XOR(I)+F(M-1)*BMT)*EI
  230 I=I+IRS
      MB=M9+1
      IF (IBT.GT.0)  HL(I)=(BDS(N)+F(M9))/(1.0-E(M9))
      DO 235 M=M1,M9
```

```
      I=I-IRS
      MB=MB-1
  235 HL(I)=E(MB)*HL(I+IRS)+F(MB)
      IF  (IBT.GT.0) HL(I-IRS)=E(MB-1)*HL(I)+F(MB-1)
  240 CONTINUE
C
C CHECK OF THE TOLERANCE
C    AND THE ITERATION NUMBER(THE RETURN IS NORMALLY MADE TO 200. BUT AT
C    THE NEXT TO LAST ITERATION WC IS SET TO 0 AND RETURN IS MADE TO 180)
C
      IF (NI+1.GT.NIP) GO TO 285
      IF (NI+1.LT.NIP.AND.RLI.GT.EPS) GO TO 180
      WC=1.0
      NIP=NI+1
      GO TO 180
  285 CONTINUE
C
C COMPUTATION OF RESIDUALS.
C
      SUM=0.0
      RRS=0.0
      SOR=0.0
      DO 275 M=M1,M9
      I=(M-1)*IRS+2
      BBM=BB(M)
      BB2=BBM+BBM+2.0
      TYM=TY(M)
      FCM=1.0/CF(M)
      BPT=BBM+TYM
      BMT=BBM-TYM
      DO 270 N=N1,N9
      RRSS=(HL(I+ICS)+HL(I-ICS)+HL(I+IRS)*BPT+HL(I-IRS)*BMT
     2-BB2*HL(I)-XOR(I))*FCM
      RRS=RRS+RRSS*RRSS
      SUM=SUM+1.0
      SOR=SOR+ABS(XOR(I)*FCM)
  270 I=I+ICS
  275 CONTINUE
      RRS=SQRT(RRS/SUM)
      SOR=SOR/SUM
      PCT=100.0*RRS/SOR
C
C PRINTOUT OF RESIDUAL AND CCMPUTER TIME INFORMATION.
C
          IF (DEBUG)
    2PRINT 500,SOR,RRS,PCT,    NI
  500 FORMAT(69H  AVE ABS(FOR)    RESIDUAL       PERCENT
     1   NO OF ITER./1X,E12.4,3E14.4,I8)
C
C ADJUSTMENT OF SCALAR FIELD HL (ANAL) TO THE SPECIFIED AVERAGE VALUE.
C
      IF (IBT.LT.1)  GO TO 400
      HLI=0.0
      SUM=0.0
      DO 390 M=M1,M9
      I=(M-1)*IRS+1
```

```
      DO 390 N=N1,N9
      I=I+ICS
      SUM=SUM+1.0
  390 HLI=HLI+HL(I)
      HLI=HLI/SUM
      HLI=AVE-HLI
      DO 395 M=1,NR
      I=(M-1)*IRS+1
      DO 395 N=1,NC
      HL(I)=HL(I)+HLI
  395 I=I+ICS
      HL(1)=(HL(2)+HL(1+NC))*0.5
      HL(NC)=(HL(NC-1)+HL(NC+NC))*0.5
      HL(I9M)=(HL(I9M+1)+HL(I9M-NC))*0.5
      HL(I9)=(HL(I9-1)+HL(I9-NC))*0.5
  400 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE ADVEC(DT,US,VS,Q1,Q2,CM)
C
C THIS SUBROUTINE ADVECTS THE FIELD Q1 WITH A SPECIFIED WIND.
C
C   DT = TIME STEP OVER WHICH ADVECTION IS MADE
C   US,VS = COMPONENTS OF WIND USED TO ADVECT Q1 FIELD
C   Q1 = FIELD THAT IS ADVECTED
C   Q2 = DUMMY FIELD
C   CM = COSINES OF ROW LATITUDES
C
      DIMENSION Q1(1),Q2(1),CM(1)
      COMMON/CGD/ M9,N9,I9,M8,N8,YB,XB,DD
      XID=1.0
      YID=XID*N9
      TT=DT
      UT=US
      VT=VS
      IT=1
      DO 20 IR=1,10
      IF (UT.LT.1.0.AND.VT.LT.1.0) GO TO 22
      UT=0.5*UT
      VT=0.5*VT
      TT=0.5*TT
   20 IT=IT+1
   22 CON =ABS(TT)
      DO 200 IR=1,IT
      I=1
      DO 100 M=1,M9
      CMI=1.0/CM(M)
      DO 100 N=1,N9
      Q1I=Q1(I)
      UA=ABS(UT)*CMI
      VA=ABS(VT)
      IF (DT.LT.0.0) GO TO 80
      IU=N-SIGN(XID,UT)
      IV=I+SIGN(YID,VT)
      GO TO 90
   80 IU=N+SIGN(XID,UT)
      IV=I-SIGN(YID,VT)
   90 Q1V=0.0
      Q1U=0.0
      IF (IV.GT.0.AND.IV.LE.I9) Q1V=Q1(IV)
      JU=IU+(M-1)*N9
      IF (IU.GT.0.AND.IU.LE.N9) Q1U=Q1(JU)
      Q2(I)=Q1I-((Q1I-Q1U    )*UA+(Q1I-Q1V    )*VA)*CON
  100 I=I+1
      DO 150 I=1,I9
  150 Q1(I)=Q2(I)
  200 CONTINUE
      RETURN
      END
```

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Appendix D

AAR PROGRAM LISTING

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```
      PROGRAM AAR(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
     1TAPE7=PUNCH,TAPE1,TAPE2,TAPE3)
C
C     THIS PROGRAM DECODES METEOROLOGICAL DATA OBTAINED WITH THE
C     USA AUTOMATIC MET SYSTEM AT THE WHITE SAND MISSLE RANGE DURING OCT
C     /NOV 1974. (REVISED FOR UNIVAC,JUNE 1975)
C

CH    20 MAY 75

CH    PROGRAM AAR READS VARIOUS INPUT DATA DESCRIBED AS COMMENTS IN
CH    IN PROGRAM AND COMPUTES A FINAL FORECAST CURVE (HEIGHT,VIRTUAL
CH    TEMP IN DEG.C. ,U AND V COMP.) FOR A SPECIFIED FIRING TIME AND
CH    FIRING LOCATION

      DOUBLE PRECISION XX,YY,XL,YL,RAD
      INTEGER ABCDEF(14),GHIJKL(10),MNOPQR(10)
      INTEGER H1(7,7),T1(7,7),U1(7,7),V1(7,7)
      DIMENSION HH(49,4,2),TV(49,4,2),U(49,4,2),V(49,4,2),XMILS1(21),
     1HHFNAL(4,2),TVFNAL(4,2),UFINAL(4,2),VFINAL(4,2),XNOTS1(21)
      DIMENSION JSAV(5),TIM(5),CDIS(21),XNDU(21),XNDV(21),XNDTC(21),
     1XNDT(21),XNDH(21),XNOTS2(21),XMILS2(21),DIFSEC(21)
      DIMENSION UF(21),VF(21),TF(21),HF(21),PF(21),PFD(5),X(7),Y(7)
      DIMENSION   UR(12,12),VR(12,12),HR(12,12),TR(12,12)
      DIMENSION IUM(147),XS(25),YS(25),ES(25),IMD(12),PR(12,12)
      DIMENSION HHTFG(5),STV(5),        HHTF(5),TVTF(5),UTF(5),VTF(5)
      COMMON /FMT/ XLAB
      EQUIVALENCE(I7,NX),(J7,NY)

      DATA STV/111.0,1457.0,3012.0,5574.0/
      DATA IDIF,IGMT/20,-420/
      DATA L1,L4,L12/1,4,12/
      DATA IND,YMAX,YMIN/21,300.0,1000.0/
      DATA JSAV/10,1,9,10,10/
      DATA TIM /1700.,1830.,2000.,2130.,2300./
      DATA PFD/870.0,850.0,700.0,500.0,0.0/
      DATA IMD/0,31,59,90,120,151,181,212,243,273,304,334/

2     FORMAT(1X,19H NO DATA FOR TFIRE=,F7.1)
3     FORMAT(1H1)
4     FORMAT(8F10.2)
5     FORMAT(10X,3F10.2)
10    FORMAT (13A6,A2)
12    FORMAT(/65H           LATITUDE        LONGITUDE
     1              ,/,2F15.2)
13    FORMAT(/15X,9HNORTHING=,D20.8,18H            EASTING=,D20.8)
30    FORMAT(1X,I2,F7.2,F10.2,F5.2,I5,12X,F8.2,F10.2,F5.2,I5)
42    FORMAT(5X,2I5,2F10.2,2I10)

      PRINT 3
      PRINT 1100
      PRINT 3

CH    THE NEXT DATA SET IS INPUT READ FROM DATA CARDS (VARIABLES ARE
CH    DESCRIBED IN COMMENT CARDS THAT FOLLOW
```

```
      READ(5,10) ABCDEF
      WRITE(6,10) ABCDEF
      READ(5,30) IQ,XFIRE,XUL,XD,NX,YFIRE,YUL,YD,NY
      WRITE(6,30) IQ,XFIRE,XUL,XD,NX,YFIRE,YUL,YD,NY
      PRINT 1002
      READ(5,10) GHIJKL
      WRITE(6,10) GHIJKL
      READ(5,42)NT,NL,TFCST,TFIRE,IDATE,JSTAT
      WRITE(6,42)NT,NL,TFCST,TFIRE,IDATE,JSTAT
      PRINT 1002
      PRINT 1002
      WRITE(6,1005)
      PRINT 1002
      READ(5,10) MNOPQR
      WRITE(6,10) MNOPQR
      READ 5,(XS(J),YS(J),ES(J),J=1,JSTAT)
      PRINT 5,(XS(J),YS(J),ES(J),J=1,JSTAT)

CH    ABCDEF=HEADER LABEL CARD FOR FOLLOWING DATA
CH    IQ=INDICATOR SHOWING HOW FINAL DATA IS TO BE PRINTED
CH    1 PRINTS HARD COPY OF CURVES AND DATA FOR CURVES
CH    -1 PRINTS CURVES ONLY

CH    XFIRE=LONGITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
CH    XUL=LONGITUDE OF UPPER LEFT HAND CORNER OF GRID
CH    XD=DISTANCE (DEGREES AND TENTHS) BETWEEN GRID POINTS IN X (LONG.)
CH    NX=NUMBER OF MINI GRID ARRAY POINTS IN X DIRECTION (LONGITUDE)
CH    YFIRE=LATITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
CH    YUL=LATITUDE OF UPPER LEFT HAND CORNER OF GRID
CH    YD=DISTANCE IN DEG. AND TENTHS BETWEEN GRID POINTS IN Y DIR. (LAT)
CH    NY=NUMBER OF MINI GRID ARRAY POINTS IN Y DIRECTION (LATITUDE)
CH    GHIJKL=HEADER LABEL CARD FOR FOLLOWING DATA
CH    NT=NUMBER OF 1 HR FCST ARRAY PERIODS INCLUDING TIME OF FCST
CH    NL=NUMBER OF LEVELS
CH    TFCST=GMT TIME OF FIRST ARRAY OF UPDATED GWC FORECAST
CH    TFIRE=GMT TIME OF FIRING (HRS AND MIN)
CH    IDATE=DATE OF GWC FORECAST
CH    JSTAT=NUMBER OF OBSERVATION STATIONS
CH    XS(J)=LONGITUDE OF REPORTING STATION IN DEG AND HNDTHS
CH    YS(J)=LATITUDE OF REPORTING STATION IN DEG AND HNDTHS
CH    ES(J)=ELEVATION OF REPORTING STATION IN METERS

      IY=INT(IDATE*0.0001)
      IM=INT(IDATE*0.01)-IY*100
      ID=IDATE-IY*10000-IM*100
      IH=INT(TFIRE)
      IMN=(TFIRE-IH)*60
      IMDATE=IMN+60*(IH+24*(ID+IMD(IM)+365*IY-366))
      REX=0.0
      REX1=0.0
      XEND=TFCST+NT-1
      CALL TIME (TFIRE,TFCST,TS,TL,ITS,ITL,XEND,REX1)
      IF (REX1.EQ.59) GO TO 600
      CALL CENTER(XFIRE,YFIRE,XUL,YUL,XD,YD,NX,NY,PN,PE,PS,PW,
     1IPN,IPE,IPS,IPW,REX)
```

```
      IF (REX.EQ.71) GO TO 600
      ITSS=ITS-1

CH    THE FCST DATE (JDATE) AND TIME (JTIME) OF GWC DATA IS NOW READ IN

      READ(1) JDATE,JTIME
      XTIME=FLOAT(JTIME)*0.01
      IF(JDATE.NE.IDATE)PRINT 1001
      IF(XTIME.NE.TFCST) PRINT 1001
CHECK IF(JDATE.NE.IDATE)GO TO 600
CHECK IF(XTIME.NE.TFCST) GO TO 600
      IF (TFIRE.GT.XEND.OR.TFIRE.LT.TFCST) PRINT2,TFIRE
CHECK IF (TFIRE.GT.XEND.OR.TFIRE.LT.TFCST) GO TO 600

CH    THE GWC FCST DATA IS SCANNED AS (DUM) TO DETERMINE THE FCST DATA
CH    ON EACH SIDE OF THE TIME OF FIRING

      PRINT 42,ITSS
      IF(ITSS.EQ.0) GO TO 202
      DO 200 JT=1,ITSS
      DO 200 JL=L1,L4
200   READ(1)IUM

CH    IN THE 211,210 DO LOOPS, THE GWC FCST DATA FOR LEVELS L1 TO L4 IS
CH    NOW READ FOR THE FCST TIME ON EACH SIDE OF THE TIME OF FIRING

202   DO 211 JT=1,2
      DO 210 JL=L1,L4
      READ(1) ((U1(J,I),V1(J,I),H1(J,I),I=1,I7),J=1,J7)
      DO 205 I=1,I7
      DO 205 J=1,J7
      IH1=INT(H1(J,I)*0.0001)
      T1(J,I)=IABS(H1(J,I)-IH1*10000)
      H1(J,I)=IH1
205      CONTINUE
      DO 209 JX=1,I7
      DO 208 JY=1,J7
      JXY=JX+(JY-1)*NX
      HH(JXY,JL,JT)=H1(JX,JY)*0.1
      TV(JXY,JL,JT)=T1(JX,JY)*0.1
      U(JXY,JL,JT)=U1(JX,JY)*0.1
208   V(JXY,JL,JT)=V1(JX,JY)*0.1
209   CONTINUE
210   CONTINUE
211   CONTINUE
      JX=IPW
      JY=IPS
      JXY=JX+(JY-1)*NX
      JWS=JXY
      JX=IPE
      JXY=JX+(JY-1)*NX
      JES=JXY
      JY=IPN
      JXY=JX+(JY-1)*NX
      JEN=JXY
      JX=IPW
```

```
      JXY=JX+(JY-1)*NX
      JWN=JXY
CH    IN THE 250 DO LOOPS, HEIGHTS, TEMPERATURES, U AND V COMPONENTS FOR
CH    THE VARIOUS LEVELS (JL=L1,L4) ARE COMPUTED FOR THE LOCATION
CH    OF XFIRE AND YFIRE

      DO 250 JT=1,2
      DO 250 JL=L1,L4
      CALL INTERP(PW,PE,HH(JWS,JL,JT),HH(JES,JL,JT),XFIRE,
     1HHXFS)
      CALL INTERP(PW,PE,HH(JWN,JL,JT),HH(JEN,JL,JT),XFIRE,
     1HHXFN)
      CALL INTERP(PS,PN,HHXFS,HHXFN,YFIRE,HHFIN)
      HHFNAL(JL,JT)=HHFIN
      CALL INTERP(PW,PE,TV(JWS,JL,JT),TV(JES,JL,JT),XFIRE,
     1TVXFS)
      CALL INTERP(PW,PE,TV(JWN,JL,JT),TV(JEN,JL,JT),XFIRE,
     1TVXFN)
      CALL INTERP(PS,PN,TVXFS,TVXFN,YFIRE,TVFIN)
      TVFNAL(JL,JT)=TVFIN
      CALL INTERP(PW,PE,U(JWS,JL,JT),U(JES,JL,JT),XFIRE,UXFS)
      CALL INTERP(PW,PE,U(JWN,JL,JT),U(JEN,JL,JT),XFIRE,UXFN)
      CALL INTERP(PS,PN,UXFS,UXFN,YFIRE,UFIN)
      UFINAL(JL,JT)=UFIN
      CALL INTERP(PW,PE,V(JWS,JL,JT),V(JES,JL,JT),XFIRE,VXFS)
      CALL INTERP(PW,PE,V(JWN,JL,JT),V(JEN,JL,JT),XFIRE,VXFN)
      CALL INTERP(PS,PN,VXFS,VXFN,YFIRE,VFIN)
      VFINAL(JL,JT)=VFIN
250   CONTINUE

CH    IN THE 260 DO LOOP, HEIGHTS, TEMPERATURES, U AND V COMPONENTS FOR
CH    THE VARIOUS LEVELS (JL=L1,L4) AT LOCATION XFIRE,YFIRE ARE COMPUTED
CH    FOR THE TIME OF FIRING (TFIRE)

      DO 260 JL=L1,L4
      CALL INTERP (TS,TL,HHFNAL(JL,1),HHFNAL(JL,2),TFIRE,HHTF(JL))
      CALL INTERP (TS,TL,TVFNAL(JL,1),TVFNAL(JL,2),TFIRE,TVTF(JL))
      CALL INTERP (TS,TL,UFINAL(JL,1),UFINAL(JL,2),TFIRE,UTF(JL))
      CALL INTERP (TS,TL,VFINAL(JL,1),VFINAL(JL,2),TFIRE,VTF(JL))
260   CONTINUE
      DO 435 LHT=L1,L4
435   HHTFG(LHT)=HHTF(LHT)+STV(LHT)-ES(IA)
      PRINT 3
      WRITE(6,1045) JDATE,JTIME
      PRINT 1110
      PRINT 1112,UTF
      PRINT 1112,VTF
      PRINT 1112,TVTF
      PRINT 1112,HHTFG

CH    SOUNDINGS OF THE AVAILABLE U.S. ARMY RAWINSONDE STATIONS (ON TAPE)
CH    ARE READ IN IN SUBROUTINE RAWIN

      I=1
      JT=JSTAT
```

```
      CALL RAWIN(I,JT,DIFSEC,ES,UR,VR,HR,PR,TR,IMC,IMDATE,IDIF,IGMT)

CH    IN DO LOOP 311, THE BEST AVAILABLE STATION IS LOCATED BASED ON THE
CH    TIME AND LOCATION OF THE SOUNDINGS AVAILABLE

      DO 311 J=1,JT
      XLOD=(XS(J)-XFIRE)*111.137*COS(YFIRE*0.01745)
      YLAD=(YS(J)-YFIRE)*111.137
      CDIS(J)=ABS(DIFSEC(J))+.5*SQRT(XLOD*XLOD+YLAD*YLAD)
311   CONTINUE
      IA=1
      CMIN=1.E+06
      DO 320 J=1,JT
      IF(CDIS(J).GT.CMIN.OR.UR(9,J).LE.0.0) GO TO 320
      CMIN=CDIS(J)
      IA=J
320   CONTINUE

CH    AT THIS POINT, THE CURVE OF THE BEST AVAILABLE SOUNDING IS
CH    PRINTED AND THE CURVES ARE MAPPED FOR BOTH THE BEST AVAILABLE AND
CH    THE UPDATED SOUNDING

      DO 400 L=1,L12
      UF(L)=UR(L,IA)
      VF(L)=VR(L,IA)
      TF(L)=TR(L,IA)
      HF(L)=HR(L,IA)
      PF(L)=PR(L,IA)
400   CONTINUE
      X(1)=XUL
      Y(1)=YUL
      DO 410 I=2,7
      X(I)=X(I-1)+XD
      Y(I)=Y(I-1)-YD
410   CONTINUE
      XMAX=20.
      XMIN=-20.
      CALL MOVCUR(UF,PF,UTF,PFD,XNDU)
      IF(IQ.LT.1) GO TO 420
      XLAB=6HU-COMP
      PRINT 1010
      CALL PNTDAT(UF,PF,XNDU,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
420   CALL MOVCUR(VF,PF,VTF,PFD,XNDV)
      IF(IQ.LT.1) GO TO 430
      XLAB=6HV-COMP
      PRINT 1011
      CALL PNTDAT(VF,PF,XNDV,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
430   CALL MOVCUR(TF,PF,TVTF,PFD,XNDT)
      IF(IQ.LT.1) GO TO 440
      XMAX=310.
      XMIN=210.
      XLAB=6H TEMP
      PRINT 1012
      CALL PNTDAT(TF,PF,XNDT,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
440   CALL MOVCUR(HF,PF,HHTFG,PFD,XNDH)
      IF(IQ.LT.1) GO TO 450
```

```
      XMAX=16000.
      XMIN=0.0
      XLAB=6HHEIGHT
      PRINT 1013
      CALL PNTDAT(HF,PF,XNDH,PF,IND,IND,XMAX,XMIN,YMAX,YMIN,BOB)
450   IF(UF(1).EQ.0.0.AND.VF(1).EQ.0.0) GO TO 460
      GO TO 500
460   IF(TF(1).EQ.0.0.AND.HF(1).EQ.0.0) PRINT 2,TFIRE
500   CONTINUE

C        WSTM CONVERSION

         RAD=0.0174532925
         YL=YFIRE*RAD
         XL=XFIRE*RAD
         CALL WSTM(YL,XL,XX,YY)
      PRINT 3
      PRINT 1046
      PRINT 1002
      PRINT 1040
      PRINT 1002
      PRINT 1020
      PRINT 1002
      PRINT 1025
      PRINT 1002

CH    IN DO LOOP 470, DATA FOR BOTH THE BEST AVAILABLE SOUNDING AND
CH    UPDATED SOUNDING ARE PRINTED (F.1 FORMAT) FOR ZONES, PRESSURE,
CH    TEMPERATURE, AND U AND V COMPONENTS

      DO 470 ND=1,12
      IF (PF(ND).GT.0.0) GO TO 523
      TF(ND)=-999.9
      UF(ND)=-999.9
      VF(ND)=-999.9
      XNDT(ND)=-999.9
      XNDU(ND) =-999.9
      XNDV(ND) =-999.9
523   PRINT 1030, ND,PF(ND),TF(ND),UF(ND),VF(ND),ND,PF(ND),
     1XNDT(ND),XNDU(ND),XNDV(ND)
470   CONTINUE
      PRINT 1002
      PRINT 12, YFIRE,XFIRE
      PRINT 3
      PRINT 1050
      PRINT 1002
      PRINT 1060
      PRINT 1002
      PRINT 1020
      PRINT 1002
      PRINT 1070
      PRINT 1002
      PRINT 1002

CH    IN DO LOOP 480, DATA FOR BOTH THE BEST AVAILABLE SOUNDING AND
CH    UPDATED SOUNDING ARE PRINTED IN COMPUTER MET MESSAGE FORMAT
```

```
      DO 480 ND=1,12
      IF(UF(ND).EQ.0.0.AND.VF(ND).EQ.0.0) GO TO 474
      DIR1=ATAN2(-UF(ND),-VF(ND))*180/3.14159
      IF (DIR1.LT.0.0) DIR1=DIR1+360
      XMILS1(ND)=DIR1*(6400.0/360.0)/10.0
      XMPS1=SQRT(UF(ND)*UF(ND)+VF(ND)*VF(ND))
      XNOTS1(ND)=1.94254*XMPS1
      GO TO 475
474   XMILS1(ND)=-999.9
      XNOTS1(ND)=-999.9
475   IF(XNDU(ND).EQ.0.0.AND.XNDV(ND).EQ.0.0) GO TO 476
      DIR2=ATAN2(-XNDU(ND),-XNDV(ND))*180/3.14159
      IF (DIR2.LT.0.0) DIR2=DIR2+360
      XMILS2(ND)=DIR2*(6400.0/360.0)/10.0
      XMPS2=SQRT(XNDU(ND)*XNDU(ND)+XNDV(ND)*XNDV(ND))
      XNOTS2(ND)=1.94254*XMPS2
      GO TO 478
476   CONTINUE
478   N=ND-1
      IXNDT=IFIX(10.0*XNDT(ND)+.5)
      IPF=IFIX(PF(ND)+.5)
      IXMIL1=IFIX(XMILS1(ND)+.5)
      IXNOT1=IFIX(XNOTS1(ND)+.5)
      IXMIL2=IFIX(XMILS2(ND)+.5)
      IXNOT2=IFIX(XNOTS2(ND)+.5)
      ITF=IFIX(10.0*TF(ND)+0.5)
      IF (PF(ND).GT.0.0) GO TO 533
      ITF   =-999
      IXNDT=-999
      IXNOT1=-999
      IXNOT2=-999
      IXMIL1=-999
      IXMIL2=-999
533   PRINT 1080,N,IPF,ITF,IXMIL1,IXNOT1,N,IPF,IXNDT,IXMIL2,IXNOT2
      WRITE (3)  N,IPF,ITF,IXMIL1,IXNOT1,N,IPF,IXNDT,IXMIL2,IXNOT2
480   CONTINUE
      PRINT 13,YY,XX
      WRITE (3)  XX,YY

1001  FORMAT(1X,46HDATE TIME OF GWC FCST DIFFERENT THAN DATA CARD)
1002  FORMAT(1X,2I15)
1005  FORMAT(17X,17HARMY STATION DATA)
1010  FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=U COMP, Y=PRESS)/)
1011  FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=V COMP, Y=PRESS)/)
1012  FORMAT(1H1,15X,44HPRINTOUT OF GRAPHICAL DATA (X=TEMP, Y=PRESS)/)
1013  FORMAT(1H1,15X,46HPRINTOUT OF GRAPHICAL DATA (X=HEIGHT, Y=PRESS)/)
1020  FORMAT(4X,23HBEST AVAILABLE SOUNDING,20X,16HUPDATED SOUNDING)
1025  FORMAT(1X,70HZONE  PRESS  TEMP  UCOMP  VCOMP       ZONE  PRESS  TE
     1MP  UCOMP  VCOMP)
1030  FORMAT(2X,I3,F7.1,F6.1,2F7.1,I11,F7.1,F6.1,2F7.1)
1031  FORMAT(//10X,5HCMIN=,F10.2,10X,3HIA=,I5)
1040  FORMAT(7X,49HPRESS IN MBS, TEMP IN DEG(K), U AND V COMP IN MPS)
1045  FORMAT(10X,10HGWC DATE =,I10,10X,10HGWC TIME =,I10//)
1046  FORMAT(16X,15HSTANDARD FORMAT)
1050  FORMAT(21X,27HCOMPUTER MET MESSAGE FORMAT)
```

```
1060  FORMAT(1X,81HPRESS IN MBS, TEMP IN TENTHS OF DEG(K), DIRECTION IN
     1TENS OF MILS, SPEED IN KNOTS)
1070  FORMAT(1X,70HZONE  PRESS  TEMP   DIR   SPEED          ZONE  PRESS  TE
     1MP   DIR   SPEED )
1080  FORMAT(2X,I3,I7,I6,2I7,I11,I7,I6,2I7)
 1100 FORMAT(///47X,30HARTILLERY APPLICATIONS ROUTINE,     //////
     2///,    57X,5HUNITS,///,53X,11HSPEED - MPS,//,53X,15HDIRECTION - DE
     3G,//,   53X,15HHEIGHT - METERS,//,53X,19HTEMPERATURE - DEG K)
 1110 FORMAT(6X,8HGWC DATA//)
 1112 FORMAT(4X,10E12.3/)

600   STOP
      END
```

```
      SUBROUTINE TIME (TFIRE,TFCST,TS,TL,ITS,ITL,TFEND,REX1)
CH    SUBROUTINE(TIME) SELECTS THE MINI GRID FORECAST ON EACH SIDE OF
CH    THE TIME OF FIRING AND INTERPOLATES TO TIME OF FIRING

CH    TFIRE=TIME OF FIRING          (HRS AND DECIMALS)
CH    TFCST=      TIME OF FIRST ARRAY OF UPDATED GWC      FORCAST
CH    TS=TIME OF FCST ARRAY THAT IS JUST SMALLER THAN TFIRE
CH    TL=TIME OF FCST ARRAY THAT IS JUST LARGER THAN TFIRE
CH    ITS=ARRAY POSITION INTEGER OF TS
CH    ITL=ARRAY POSITION INTEGER OF TL

20    FORMAT(5X,37HTFIRE IS GREATER THAN FORECAST EXTENT)
      IF (TFIRE.LT.TFCST) TFIRE=TFIRE+24.0
      IF(TFIRE.GT.TFEND)  REX1=59
      IF(TFIRE.GT.TFEND) GO TO 40
      ITS=1
      TS=TFCST
      DO 80 ITL=2,19
      TL=TFCST+ITL-1
        IF(TFIRE.LT.TL) GO TO 100
      ITS=ITL
80    TS=TL
      REX1=59
40    WRITE(6,20)
100   RETURN
      END
```

```
      SUBROUTINE CENTER(XFIRE,YFIRE,XUL,YUL,XD,YD,NX,NY,PN,PE,PS,PW,
     1IPN,IPE,IPS,IPW,REX)

CH    SUBROUTINE CENTER=SCANS JX AND JY ARRAYS AND INTERPOLATES VALUES
CH    FOR THE POSITION XFIRE AND YFIRE

CH    XFIRE=LONGITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
CH    YFIRE=LATITUDE OF CENTER OF FIRING PATH (DEGREES AND TENTHS)
CH    XUL=LONGITUDE OF UPPER LEFT HAND CORNER OF MINI GRID ARRAY
CH    YUL=LATITUDE OF UPPER LEFT HAND CORNER OF MINI GRID ARRAY
CH    XD=DISTANCE (DEGREES AND TENTHS) BETWEEN GRID POINTS IN X DIRECTION
CH    YD=DISTANCE (DEGREES AND TENTHS) BETWEEN GRID POINTS IN Y DIRECTION
CH    NX=NUMBER OF MINI GRID POINTS IN X DIRECTION (LONGITUDE)
CH    NY=NUMBER OF MINI GRID POINTS IN Y DIRECTION (LATITUDE)
CH    PN=POSITION (LATITUDE) OF THE ARRAY GRID JUST NORTH OF YFIRE
CH    PE=POSITION (LONGITUDE) OF THE ARRAY GRID JUST EAST OF XFIRE
CH    PS=POSITION (LATITUDE) OF THE ARRAY GRID JUST SOUTH OF YFIRE
CH    PW=POSITION (LONGITUDE) OF THE ARRAY GRID JUST WEST OF XFIRE
CH    IPN=ARRAY GRID NUMBER JUST NORTH OF YFIRE
CH    IPE=ARRAY GRID NUMBER JUST EAST OF XFIRE
CH    IPS=ARRAY GRID NUMBER JUST SOUTH OF YFIRE
CH    IPW=ARRAY GRID NUMBER JUST WEST OF XFIRE

100   FORMAT (1X,29H     YFIRE NORTH OF MINI GRID)
110   FORMAT (1X,29H     YFIRE SOUTH OF MINI GRID)
120   FORMAT(1X,28H     XFIRE WEST OF MINI GRID)
130   FORMAT(1X,28H     XFIRE EAST OF MINI GRID)


      PE=0.0
      PW=0.0
      PS=0.0
      PN=0.0
      IF(YUL.LT.YFIRE) PRINT 100
      YLL=YUL-YD*NY
      IF(YLL.GT.YFIRE) PRINT 110
      IF(XUL.GT.XFIRE) PRINT 120
      XUR=XUL+XD*NX
      IF(XUR.LT.XFIRE) PRINT 130
        DO 200 IX=1,7
        PE=XUL+XD*(IX-1)
        IF (PE.LT.XFIRE) GO TO 200
        IPE=IX
        PW=PE-XD
        IPW=IPE-1
        GO TO 201
200     CONTINUE
201   DO 220 IY=1,7
      PS=YUL-YD*(IY-1)
      IF(PS.GT.YFIRE) GO TO 220
      IPS=IY
      PN=PS+YD
      IPN=IPS-1
      GO TO 222
220   CONTINUE
222   RETURN
      END
```

```
      SUBROUTINE INTERP(X1,X2,Y1,Y2,X0,Y0)

CH    SUBROUTINE INTERP INTERPOLATES INTERMEDIATE VALUE OF Y0 FROM INITIAL
CH                 X1, Y1,INTERMEDIATE X0 AND FINAL X2, Y2 VALUES

      IF(Y2.LE.Y1)Y0=((X2-X0)*(Y1-Y2)/(X2-X1))+Y2
      IF(Y1.LT.Y2)Y0=((X0-X1)*(Y2-Y1)/(X2-X1))+Y1
      RETURN
      END
```

```
      SUBROUTINE  RAWIN(I,JT,TS,ES,UR,VR,HR,PR,TR,IMD,IDATE,IDIF,IGMT)
C THIS SUBROUTINE READS IN THE U.S.ARMY RAWINSONDE DATA.
C
      DIMENSION  UR(1),VR(1),HR(1),TR(1),PR(1),ES(1),TS(1),IMD(1)
      DIMENSION  DAT(512),IS(25),HOZ(17)
      DATA ACR,CKM,XNIL/0.0174533,0.5148,-999.9/
      DATA J3,J10,J12,J17,J23,J28,J51/3,10,12,144,23,28,51/
      DATA  HOZ/0.0,100.0,350.0,750.0,1250.0,1750.0,2250.0,2750.0,3250.0
     2      ,3750.0,4250.0,4750.0,5500.0,6500.0,7500.0,8500.0,9500.0/

      IMIN=1440
      DO 18 J=1,JT
   18 IS(J)=0
      DO 19 J=1,J17
      HR(J)=XNIL
      TR(J)=XNIL
      PR(J)=XNIL
      UR(J)=XNIL
   19 VR(J)=XNIL
      IF (I.GT.1) GO TO 22
C
C READS IN DATA SET
C
   20 READ 2,DAT
    2 FORMAT(10F8.1)
C
C LOOP THROUGH DATA SET IN RECORD
C
   21 DO 30 J=1,J10
   22 JC=(J-1)*J51+1
C
C CHECKS DATA FOR DATE,TIME,AND TYPE
C
      IP1=INT(DAT(JC)*1.0E-4)
      DATJ=DAT(JC)-IP1*1.0E4
      IP2=INT(DATJ*1.0E-2)
      DATJ=DATJ-IP2*1.0E2
      IP3=INT(DATJ)
      IP4=INT(DAT(JC+1)*0.01)
      IP5=DAT(JC+1)-IP4*100
      JDATE=IP5+60*(IP4+24*(IP3+IMD(IP2)+365*IP1-366))-IGMT
      IF (JDATE.LT.IDATE-IMIN) GO TO 32
      IF (JDATE.LT.IDATE-IDIF) GO TO 30
      IF (JDATE.GT.IDATE+IDIF) GO TO 32
   24 JS=INT(DAT(JC+2)*0.1)
      DAT2=DAT(JC+2)-JS*10
      IF (DAT2.LT.1.OR.DAT2.GT.3) GO TO 30
      IS(JS)=INT(DAT2)
      IF (IS(JS).EQ.1) GO TO 30
      ESJS=ES(JS)
      TS(JS)=JDATE-IDATE
C SELECTS OUT PRESSURE,TEMPERATURES AND WINDS FOR ARTILLERY ZONES
      JCJ=JC+J28-2
      JKT=1
      DO 28 JH=1,J23,2
```

```
      JK=(JS-1)*J12+JKT
      JJH=JCJ+JH
      HR(JK)=HOZ(JKT)
      IF(ABS(DAT(JJH)).GT.360.0) GO TO 27
      ANG=ACR*DAT(JJH)
      UR(JK)=-DAT(JJH+1)*SIN(ANG)*CKM
      VR(JK)=-DAT(JJH+1)*COS(ANG)*CKM
   27 IF(DAT(J3+JH).LT.0.0) GO TO 28
      PR(JK)=DAT(J3+JH)
      TR(JK)=DAT(J3+JH+1)+273.16
   28 JKT=JKT+1
   30 CONTINUE
      GO TO 20
   32 CONTINUE
      RETURN
      END
```

```
                                                                    *
      SUBROUTINE MOVCUR(XD,YD,XFD,YFD,XND)
      DIMENSION XD( 1),YD( 1),XFD(1),YFD(1),XND( 1)
      DIMENSION X(5),E(5),IY(5)
C DETERMINE THE NUMBER OF FORCAST DATA POINTS
      NPTSF=0
      DO 120 I=1,5
  120 IF(XFD(I).GT.0.0) NPTSF=NPTSF+1
C    DETERMINE THE NUMBER OF BALLOON DATA POINTS
      NPTSD=0
      DO 130 I=1,21
      IF (YD(I).LE.0.0.OR.XD(I).LT.-900.0) GO TO 132
  130 NPTSD=NPTSD+1
  132 NPTSD=NPTSD-1
C   CALCULATE X ORDINATE, ERROR, AND INDEX OF BALLOON DATA RELATIVE TO
C   FORCAST DATA
      DO 110 J=1,NPTSF
      DO 140 I=1,NPTSD
      IF(YD(I).GE.YFD(J).AND.YD(I+1).LT.YFD(J)) GO TO 100
  140 CONTINUE
      IF (YFD(J).LT.YD(1)) GO TO 142
      X(J)=XD(NPTSD+1)
      IY(J)=NPTSD+1
      E(J)=XFD(J)-X(J)
      GO TO 110
  142 X(J)=XD(1)
      IY(J)=0
      E(J)=XFD(J)-X(J)
      GO TO 110
  100 CONTINUE
      X(J)=(YD(I)-YFD(J))*(XD(I+1)-XD(I))/(YD(I)-YD(I+1))+XD(I)
      E(J)=XFD(J)-X(J)
      IY(J)=I
  110 CONTINUE
      IS=IY(1)
      IF (IS.LT.1) GO TO 150
      DO 190 I=1,IS
  190 XND(I)=XD(I)+E(1)
  150 NPTSF=NPTSF-1
      DO 200 J=1,NPTSF
      EF=(E(J+1)-E(J))/(YFD(J+1)-YFD(J))
      IS=IY(J)+1
      DO 180 I=IS,NPTSD
      XND(I)=XD(I)+(YD(I)-YFD(J))*EF+E(J)
      IF(I.GE.IY(J+1))GO TO 200
  180 CONTINUE
  200 CONTINUE
      IS=IY(NPTSF+1)
      NPTSD=NPTSD+1
      DO 170 I=IS,NPTSD
  170 XND(I)=XD(I)+E(NPTSF+1)
      RETURN
      END
```

*This subroutine was written by Len Gasiorek (SRI)

```
      SUBROUTINE PNTDAT(XD,YD,XZ,YZ,N,M,XMAX,XMIN,YMAX,YMIN,BOB)*
C     THIS PROGRAM PRODUCES NSETS NUMBER OF PRINTER-GRAPHS OF X,Y
C     DATA ROUNDED TO THE NEAREST DELX AND DELY.
C     INPUT ...
C     XD = X-DATA FOR FIRST SET.
C     YD = Y-DATA FOR FIRST SET.
C     XZ = X-DATA FOR SECOND SET.
C     YZ = Y-DATA FOR SECOND SET.
C     XMAX,XMIN,YMAX,YMIN = MAX AND MIN OF DATA.
C     N,M = TOTALS OF D AND Z TYPE DATA.
C     XLAB,YLAB = X AND Y LABELS.
C
      DIMENSION XD( 1),YD( 1),XZ( 1),YZ( 1)
      COMMON /FMT/ XLAB
    2 FORMAT (1H )
    4 FORMAT(1X,3HX =,10E12.3)
    5 FORMAT(1X,3HY =,10E12.3)
    6 FORMAT(4X,10E12.3)
    7 FORMAT(6X,19HBEST AVAILABLE DATA)
    8 FORMAT(6X,16HGWC UPDATED DATA)
      PRINT 2
      PRINT 2
      PRINT 7
      PRINT 2
30    PRINT 4,(XD(L),L=1,10)
      PRINT 6,(XD(L),L=11,N)
40    PRINT 2
      PRINT 5,(YD(L),L=1,10)
      PRINT 6,(YD(L),L=11,N)
      PRINT 2
      PRINT 8
      PRINT 2
60    PRINT 4,(XZ(L),L=1,10)
      PRINT 6,(XZ(L),L=11,M)
70    PRINT 2
      PRINT 5,(YZ(L),L=1,10)
      PRINT 6,(YZ(L),L=11,M)
      IF (XMAX.NE.-0.0) GO TO 120
      XMAX=-1.0E300
      YMAX=-1.0E300
      XMIN=1.0E300
      YMIN=1.0E300
      DO 100 I=1,N
      XMAX=AMAX1(XMAX,XD(I))
      YMAX=AMAX1(YMAX,YD(I))
      XMIN=AMIN1(XMIN,XD(I))
      YMIN=AMIN1(YMIN,YD(I))
 100  CONTINUE
```


*This subroutine was written by Hisao Shigeishi (SRI)

```
      DO 110 I=1,M
      XMAX=AMAX1(XMAX,XZ(I))
      YMAX=AMAX1(YMAX,YZ(I))
      XMIN=AMIN1(XMIN,XZ(I))
      YMIN=AMIN1(YMIN,YZ(I))
110   CONTINUE
120   CALL PNTMAP(XD,YD,XZ,YZ,N,M,XMAX,XMIN,YMAX,YMIN)
      RETURN
      END
```

```
      SUBROUTINE PNTMAP(XD,YD,XZ,YZ,N,M,XMAX,XMIN,YMAX,YMIN)*
      DIMENSION XD( 1),YD( 1),XZ( 1),YZ( 1)
      DIMENSION X(21),Y(21),A(21,21)
      COMMON /FMT/ XLAB
      DATA YLAB/6H PRESS/
    1 FORMAT (/1H ,10X,13HX-INCREMENT =,F10.3,2X,18H AND Y-INCREMENT =,
     1F10.3//1H ,A6)
    2 FORMAT (1H ,62XA6)
    3 FORMAT(/1X,F6.1,1X,1H(,21(2XA1))
    4 FORMAT(/1H ,10X,1H',20(2X1H'))
    5 FORMAT(1H ,F11.1,4F15.1)
    6 FORMAT(5X,79HIN THE FOLLOWING GRAPH + = BEST AVAILABLE SOUNDING AN
     1D X = GWC UPDATED SOUNDING)
    8 FORMAT (1H )
      DO 10 J=1,21
C$    ARRAYS
      DO 10 I=1,21
   10 A(J,I)=1H
C     OBTAIN XRANGE, YRANGE, DELX AND DELY.
      XRANGE=XMAX-XMIN
      DELX=XRANGE/(N-1)
      YRANGE=YMAX-YMIN
      DELY=YRANGE/(N-1)
C     DETERMINE THE X AND Y VALUES FOR THE AXES.
      X(1)=XMIN
      Y(1)=YMIN
      DO 100 I=2,N
      X(I)=X(I-1)+DELX
      Y(I)=Y(I-1)+DELY
  100 CONTINUE
C     DETERMINE THE IX, IY INDICES FOR ARRAY A WHICH HAS THE ITH CO
C     RELATED TO DELX AND JTH ROW RELATED TO DELY.  FOR DATA
C     SET 1 AND FOR SET 2, INSERT AN X.
      DO 110 I=1,N
      IX=(XD(I)-XMIN)/DELX + 1.5
      JX=(YD(I)-YMIN)/DELY + 1.5
      IF(IX.GT.21.OR.IX.LT.1) GO TO 110
      IF(JX.GT.21.OR.JX.LT.1) GO TO 110
      A(IX,JX)=1H+
  110 CONTINUE
      DO 120 I=1,M
      IX=(XZ(I)-XMIN)/DELX + 1.5
      JX=(YZ(I)-YMIN)/DELY + 1.5
      IF(JX.GT.21.OR.JX.LT.1) GO TO 120
      IF(IX.GT.21.OR.IX.LT.1) GO TO 120
      A(IX,JX)=1HX
  120 CONTINUE
C     PRODUCE THE PRINTER GRAPH WITH AXES X AND Y AND ARRAY A.
      PRINT 1004
 1004 FORMAT(1H1)
      PRINT 8
```

---

*This subroutine was written by Hisao Shigeishi (SRI)

```
      PRINT 8
      PRINT 8
      PRINT 6
      PRINT 1,DELX,DELY,YLAB
      II=N+1
      DO 130 I=1,N
      II=II-1
      PRINT 3,Y(II),(A(J,II),J=1,N)
130   CONTINUE
      PRINT 4
      PRINT 5,(X(L),L=1,N,5)
      PRINT 2,XLAB
      RETURN
      END
```

```
      SUBROUTINE WSTM (YLAT,XLON, XX, YY)*
C
C     CONVERSION PROGRAM CONVERTS GEODETIC POSITION TO WSTM
C
C           YLAT = NORTH LATITUDE IN RADIANS
C           XLON = WEST LONGITUDE IN RADIANS
C           XX = X (WSTM EASTING) - FT
C           YY = Y (WSTM NORTHING) - FT

      DOUBLE PRECISION XX,YY,YLAT,XLON,NN, AA, BB, N, A, B, C, D, E, V,
     1      ESQ, EPSQ, K0, SINE1, DLAM, II, METERS, P, A6, IV, VV, B5,
     2     III, KK, CM, EE,DTANX
      DATA AA, BB, SINE1, METERS / 6378206.4D0, 6356583.8D0,
     1     0.484813681109536D-5, 3.280833333333333D0 /


      CM = 382800.0D0 * SINE1
      DLAM = CM - XLON
      DLAM = DLAM / SINE1
      KK = 3.282064138D0
    1 N = (AA - BB) / (AA + BB)
      ESQ = (AA ** 2 - BB ** 2) / AA ** 2
    2 EPSQ = (AA ** 2 - BB ** 2) / BB ** 2
      A = AA * (1.0D0 - N + 1.25D0 * (N ** 2 - N ** 3) + 1.265625D0 *
     1     (N ** 4 - N ** 5))
      B = 1.5D0 * AA * (N - N ** 2 + 0.875D0 * (N ** 3 - N ** 4) +
     2     0.859375D0 * N ** 5)
      C = 0.9375D0 * AA * (N ** 2 - N ** 3 + 0.75D0 * (N ** 4 - N ** 5))
      D = (35.0D0 / 48.0D0) * AA * (N ** 3 - N ** 4 + 0.6875D0 * N ** 5)
      E = 0.615234375D0 * AA * (N ** 4 - N ** 5)
      K0 = 0.9996D0
      V = AA / (1.0D0 - ESQ * (DSIN(YLAT)) ** 2) ** 0.5
         NN = A * YLAT - B * DSIN(2.0D0 * YLAT) + C * DSIN (4.0D0 *
     1     YLAT) - D * DSIN (6.0D0 * YLAT) + E * DSIN (8.0D0 * YLAT)
      NN = NN * K0
   62 P = DLAM * 1.0D-4
      II = ((V * DSIN(YLAT) * DCOS (YLAT) * SINE1 ** 2) / 2.0D0) * K0
     1     * 1.0D8
      DTANX=DSIN(YLAT)/DCOS(YLAT)
      III = ((V * SINE1 ** 4 * DSIN (YLAT) * (DCOS (YLAT)) ** 3) /
     1     24.0D0) * (5.0D0 - (DTANX       ) ** 2 + 9.0D0 * EPSQ * (DCOS
     2     (YLAT)) ** 2 + 4.0D0 * EPSQ ** 2 * (DCOS (YLAT)) ** 4) *
     3     K0 * 1.0D16
      A6 = (P ** 6 * (V * SINE1 ** 6 * DSIN (YLAT) * (DCOS (YLAT)) **
     1    5) / 720.0D0) * (61.0D0 - 58.0D0 * (DTANX       ) ** 2 + (
     2     DTANX       ) ** 4 + 270.0D0 * EPSQ * (DCOS (YLAT)) ** 2 -
     3     330.0D0 * EPSQ * (DSIN (YLAT)) ** 2) * K0 * 1.0D24
   65 IV = V * DCOS (YLAT) * SINE1 * K0 * 1.0D4
      VV = ((V * SINE1 ** 3 * (DCOS (YLAT)) ** 3) / 6.0D0) * (1.0D0 -
     1     (DTANX       ) ** 2 + EPSQ * (DCOS (YLAT)) ** 2) * K0 *
     2     1.0D12
      B5 = DABS (P**5) * ((SINE1**5 * V * (DCOS (YLAT)) ** 5) / 120.0D0
     1   * (5.0D0 - 18.0D0 * (DTANX       ) ** 2 + (DTANX       ) ** 4
     2     + 14.0D0 * EPSQ * (DCOS (YLAT)) ** 2 - 58.0D0 * EPSQ * (DSIN
     3     (YLAT)) ** 2)) * K0 * 1.0D20
```

*This subroutine was provided by ASL of the U.S. Army Electronics Command

```
 80     YY = (NN + II * P ** 2 + III * P ** 4 - 3528252.823D0) * KK
    EE = (DABS (IV * P) + DABS (VV * P ** 3) + B5) * KK
    IF (P) 84,86,86
 84 XX=500000.0D0-EE
    GO TO 100
 86 XX=500000.0D0+EE
100 RETURN
    END
```

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REANALYSIS AND APPLICATION COMPUTER PROGRAMS FOR IMPROVING ARTI--ETC(U)
JAN 76 R L MANCUSO, R G HADFIELD DAAB07-74-C-0181

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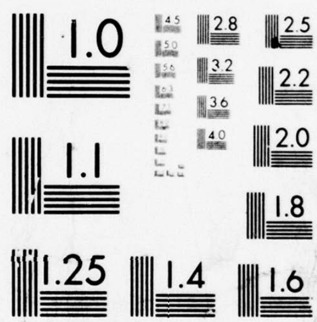

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Appendix E

PDRR DATA INPUT[*]

[*] This Appendix and the following Appendices (F,G, and H) provide an example of how both GWC prognostic information and Army Meteorological observations are used to obtain a Computer Met Message for an artillery firing for a requested time and location.

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INPUT DATA FOR PDRR ROUTINE

CARD A	1	1	1	1	1	1	1
CARD B	7	7	-106.70	32.80	.10	15.50	40.50
CARD C	1						
CARDS D	YEAR	MONTH	DAY	HOUR	MIN		
	74	11	19	12	30		
CARD E	10						

CARDS F STATION INFORMATION (Locations of Artillery Met Sections)*

NUMBER	LONGITUTE	LATITUTE	ELEVATION	
1	-106.32	32.40	1230.00	(LC-36, TSX)
2	-106.15	32.40	1311.00	(Orogrande, ORO)
3	-106.90	32.27	1350.00	(Las Cruces, LSX)
4	-106.18	32.27	1249.00	(MacGregor, MCG)
5	-106.40	32.27	1220.00	(War Road, WAR)
6	-106.48	32.40	1247.00	(MTTR, MTR)
7	-106.42	32.47	1220.00	(Small Missile Range, SMR)
8	-106.15	32.50	1230.00	(Rampart, RAM)
9	-106.38	32.62	1210.00	(Apache, APA
10	-106.08	32.85	1250.00	(Holloman, HMS)

*Explanations in parenthesis do not appear on actual computer output
(See Table 2 for definitions of input parameters)

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Appendix F

AAR DATA INPUT

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IQ	XFIRE	XUL	XD	NX	YFIRE	YUL	YD	NY *
1	-106.23	-106.70	.10	7	32.47	32.80	.10	7

NT	NL	TFCST	TFIRE	IDATE	JSTAT
19	4	0.00	12.30	741119	10

ARMY STATION DATA

LONGITUDE	LATITUDE	ELEVATICN
-106.32	32.40	1230.00
-106.15	32.40	1311.00
-106.90	32.27	1350.00
-106.18	32.27	1249.00
-106.40	32.27	1220.00
-106.48	32.40	1247.00
-106.42	32.47	1220.00
-106.15	32.50	1230.00
-106.38	32.62	1210.00
-106.08	32.85	1250.00

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*See Table 3 for explanation of input parameters

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Appendix G

PDRR DATA OUTPUT

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PROGNOSTIC DATA REANALYSIS ROUTINE

UNITS

SPEED - MPS

DIRECTION - DEG

HEIGHT - METERS

TEMPERATURE - DEG K (Virtual)

RESULTS FOR LEVEL L = 2 (850 mb)

DELETED DATA

LAT(DEG)	LON(DEG)	U(KTS)	V(KTS)	TEST

STATION DATA

NUMBER	D VALUE	TEMPERATURE	U COMP	V COMP
1	29.00	288.86	10.99	-.03
2	15.00	283.76	10.41	.18
3	40.00	290.36	8.23	-2.87
4	-999.90	-999.90	-999.90	-999.90 *
5	16.00	289.26	5.52	.45
6	-999.90	-999.90	-999.90	-999.90
7	-999.90	-999.90	-999.90	-999.90
8	-27.00	289.96	4.02	-.01
9	29.00	290.86	1.24	.86
10	28.00	288.16	4.39	2.88

* -999.90 means missing data from Artillery Met Sections

GWC DATA ON MINI GRID*

D VALUES

40	40	39	39	39	39	39
40	40	40	40	40	39	39
41	41	41	40	40	40	40
42	41	41	41	41	41	41
42	42	42	42	42	41	41
43	43	42	42	42	42	42
43	43	43	43	43	43	42

TEMPERATURE

288	289	289	289	289	289	289
289	289	289	289	289	289	289
289	289	289	289	289	289	289
289	289	289	289	289	289	289
289	289	289	289	289	289	290
289	289	289	289	289	290	290
289	289	289	289	290	290	290

U COMP

1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	2
1	1	1	1	1	2	2

V COMP

5	5	5	5	5	5	5
5	5	5	5	5	5	5
5	5	5	5	5	5	5
5	5	5	5	5	5	5
5	5	5	5	5	5	5
5	5	5	5	5	5	5
5	5	5	5	5	5	5

---

*For 1230 GMT, 19 November 1974 as interpolated from original GWC prognoses data.

UPDATED GWC DATA ON MINI GRID*

D VALUES

20	21	36	39	41	39	32
19	24	34	32	30	27	25
29	25	29	34	33	29	22
33	29	29	30	29	25	2
36	30	29	29	26	19	7
38	32	30	27	25	20	22
35	32	37	27	26	25	24

TEMPERATURE

289	290	291	291	290	289	288
289	290	291	291	290	289	288
290	290	291	291	290	289	288
290	290	291	290	289	289	289
290	290	291	290	288	286	285
290	290	289	289	288	286	285
289	289	289	289	288	287	287

U COMP

0	-1	-1	-0	1	3	4
1	1	1	1	1	1	3
2	2	2	2	2	2	3
4	4	3	4	4	4	3
6	7	5	6	7	8	8
7	7	7	6	7	8	9
6	6	3	6	7	7	6

V COMP

4	3	3	1	1	1	3
4	3	2	-0	1	0	2
3	2	2	1	2	2	2
2	2	2	1	1	1	1
0	1	3	2	1	1	1
-1	1	1	3	2	2	2
1	1	2	2	3	3	3

*For 1230 GMT, 19 November 1974 after modification to fit Army observations at WSMR taken between 1210 and 1250 GMT.

Appendix H

AAR DATA OUTPUT*

---

*This example uses data from updated minigrid and the best available Army rawinsonde to produce a Computer Met Message for 1230 GMT, 19 November 1974, and for the location requested in the input parameters (See Appendix F).

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ARTILLERY APPLICATIONS ROUTINE

UNITS

SPEED - MPS

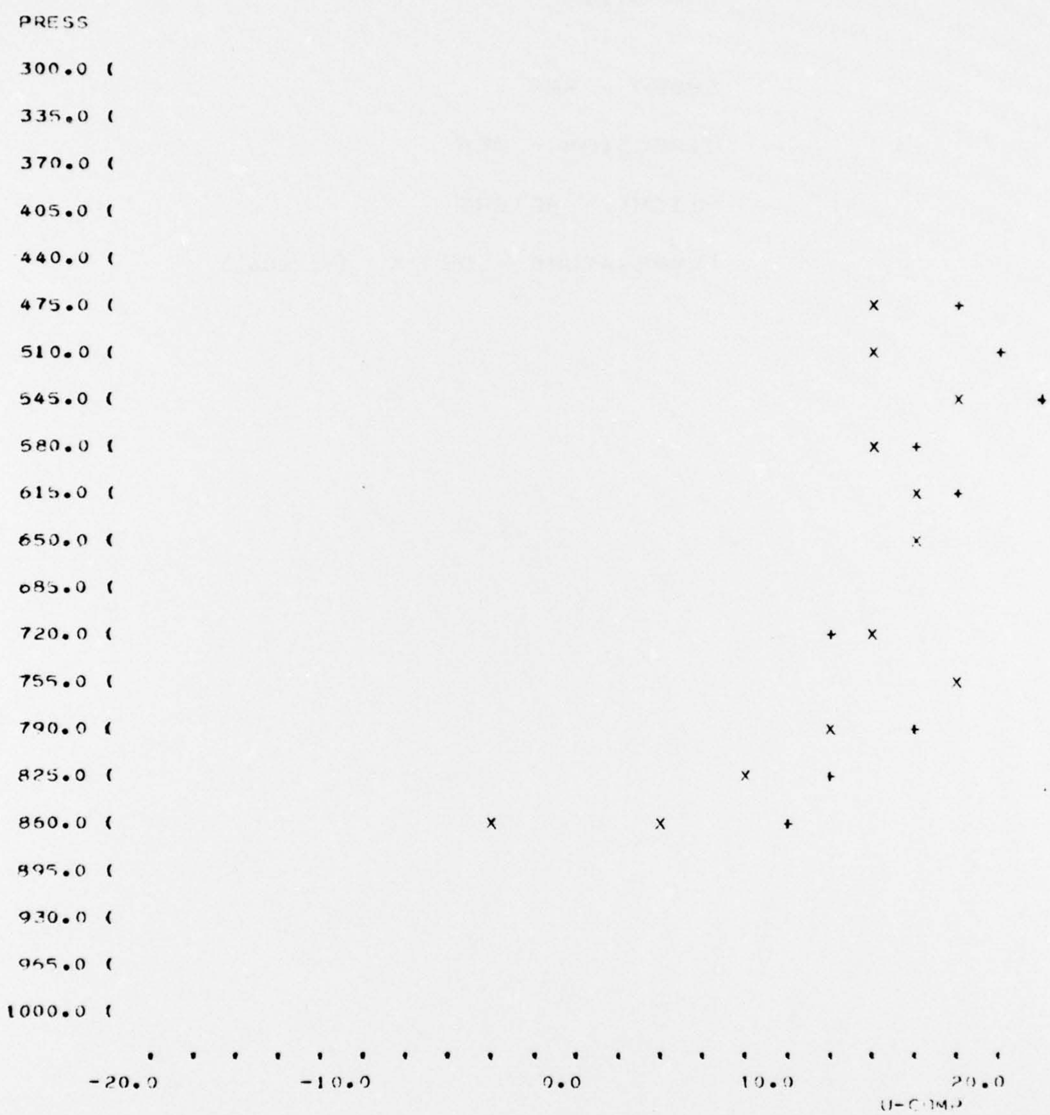
DIRECTION - DEG

HEIGHT - METERS

TEMPERATURE - DEG K (Virtual)

IN THE FOLLOWING GRAPH + = BEST AVAILABLE SOUNDING AND X = GWC UPDATED SOUNDING*

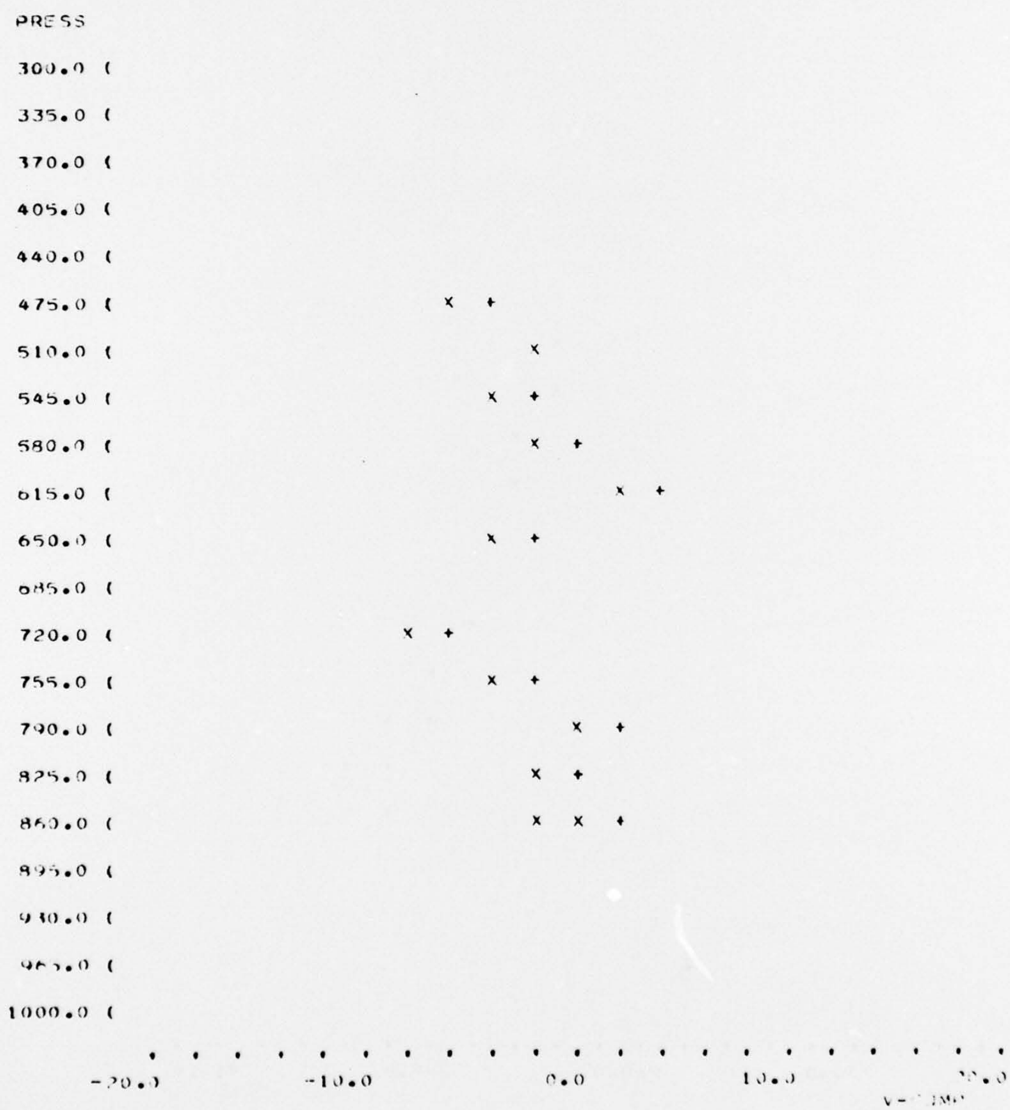
X-INCREMENT = 2.000 AND Y-INCREMENT = -35.000



* See Figure 4 for explanation of profiles.

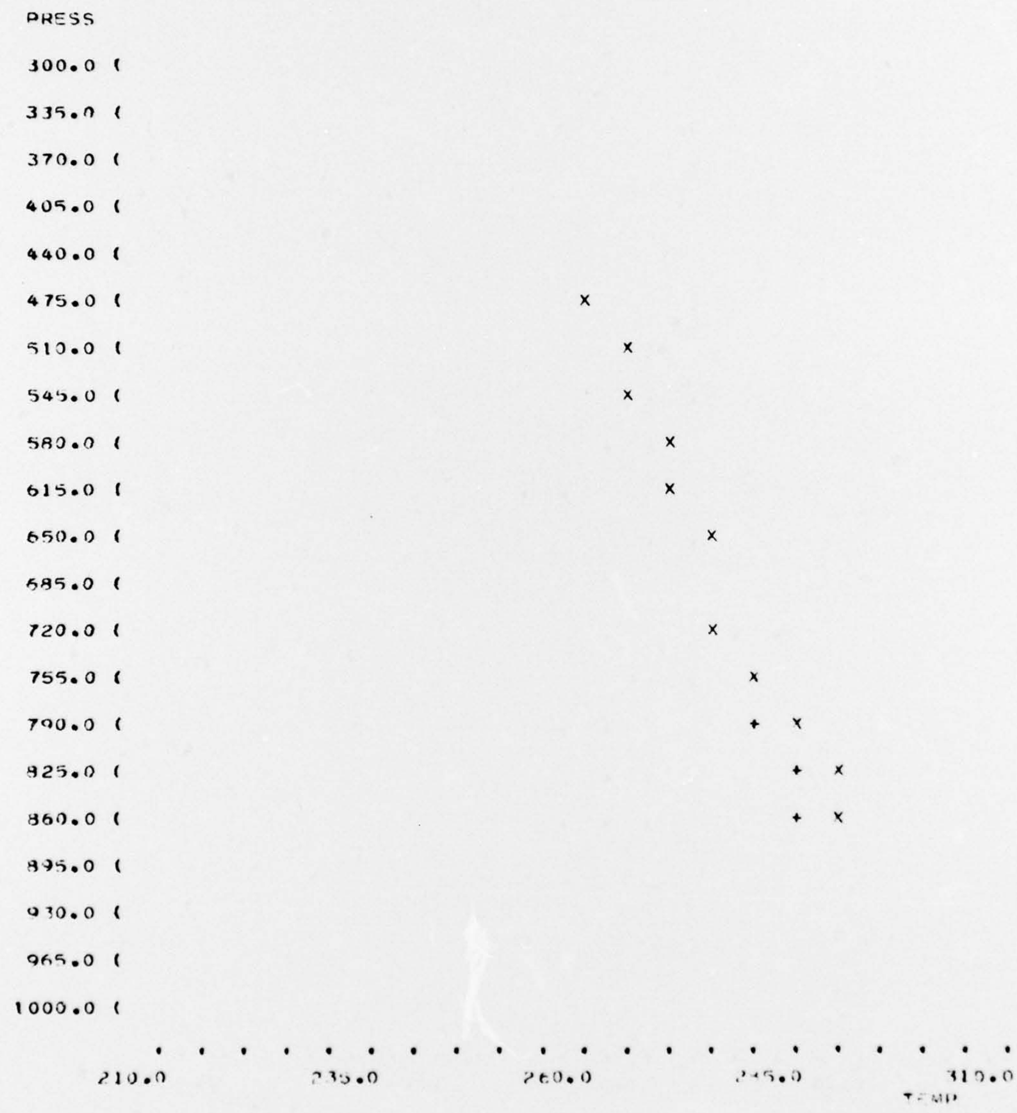
IN THE FOLLOWING GRAPH + = BEST AVAILABLE SOUNDING AND X = GWC UPDATED SOUNDING

X-INCREMENT = 2.000 AND Y-INCREMENT = -35.000



IN THE FOLLOWING GRAPH + = BEST AVAILABLE SOUNDING AND X = GWC UPDATED SOUNDING

X-INCREMENT = 5.000 AND Y-INCREMENT = -35.000



```
IN THE FOLLOWING GRAPH + = BEST AVAILABLE SOUNDING AND X = GWC UPDATED SOUNDING

          X-INCREMENT =    800.000    AND Y-INCREMENT =    -35.000

 PRESS

 300.0 (
 335.0 (
 370.0 (
 405.0 (
 440.0 (
 475.0 (             + X
 510.0 (           +   X
 545.0 (           + X
 580.0 (         +   X
 615.0 (       +   X
 650.0 (       + X
 685.0 (
 720.0 (     +   X
 755.0 (     + X
 790.0 (   + X
 825.0 ( +   X
 860.0 ( X
 895.0 (
 930.0 (
 965.0 (
1000.0 (

         . . . . . . . . . . . . . . . . . . . . .
        0.0      4000.0    8000.0    12000.0   16000.0
                                              HEIGHT
```

STANDARD FORMAT

PRESS IN MBS, TEMP IN DEG(K), U AND V COMP IN MPS

BEST AVAILABLE SOUNDING*

ZONE	PRESS	TEMP	UCOMP	VCOMP
1	876.0	287.0	3.6	2.0
2	866.0	286.6	9.8	.3
3	840.0	285.2	12.3	.4
4	801.0	282.0	15.3	1.8
5	753.0	278.7	18.4	-2.2
6	708.0	275.2	12.8	-5.3
7	666.0	273.1	15.4	-1.5
8	625.0	270.8	18.1	4.0
9	587.0	268.9	17.0	.3
10	550.0	267.1	21.5	-2.5
11	516.0	264.1	19.5	-1.2
12	484.0	259.8	18.4	-4.8

UPDATED SOUNDING**

ZONE	PRESS	TEMP	UCOMP	VCOMP
1	876.0	289.0	-3.7	.3
2	866.0	288.8	3.1	-1.4
3	840.0	288.1	8.0	-1.3
4	801.0	284.2	12.4	.1
5	753.0	280.0	17.3	-3.9
6	708.0	275.7	13.4	-7.0
7	666.0	273.4	15.3	-3.2
8	625.0	270.9	16.9	2.3
9	587.0	268.9	14.7	-1.4
10	550.0	267.0	18.2	-4.2
11	516.0	263.8	14.9	-2.9
12	484.0	259.5	13.8	-6.5

LATITUDE	LONGITUDE	
32.47	-106.23	(Midpoint of Trajectory)

COMPUTER MET MESSAGE FORMAT

PRESS IN MBS, TEMP IN TENTHS OF DEG(K), DIRECTION IN TENS OF MILS, SPEED IN KNOTS

BEST AVAILABLE SOUNDING

ZONE	PRESS	TEMP	DIR	SPEED
0	876	2870	427	8
1	866	2866	477	19
2	840	2852	477	24
3	801	2820	468	30
4	753	2787	492	36
5	708	2752	520	27
6	666	2731	490	30
7	625	2708	458	36
8	587	2689	478	33
9	550	2671	492	42
10	516	2641	486	38
11	484	2598	506	37

UPDATED SOUNDING

ZONE	PRESS	TEMP	DIR	SPEED
0	876	2890	169	7
1	866	2888	524	7
2	840	2881	497	16
3	801	2842	479	24
4	753	2800	502	34
5	708	2757	529	29
6	666	2734	501	30
7	625	2709	466	33
8	587	2689	490	29
9	550	2670	503	36
10	516	2638	499	29
11	484	2595	525	30

NORTHING= 3.12748448D+08 EASTING= 1.64633777D+07

---

*The best available sounding is defined in Section III of this report

**The updated sounding is a prognostic Computer Met Message based on both Army observations and Air Force GWC numerical forecast.

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